Final Report

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Project

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REGIONAL DETERMINATION OF ECONOMIC AVAILABILITY OF HARVESTING RESIDUES

REPORT COMPILED BY

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Canada/New Brunswick Conservation and Renewable Energy Demonstration Program

The Conservation and Renewable Energy Demonstration Program Program is administered in New Brunswick by the Energy Secretariat and managed jointly with Energy, Mines and Resources Canada. The Program is designed to help demonstrate promising conservation and renewable energy technologies, to develop public awareness and understanding of these technologies, and to create employment in new or existing industries.

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This final report is based on a project which was financially supported by the Energy Demonstration Program. For further information on other demonstration projects funded in New Brunswick under this program, contact:

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INTRODUCTION

This report is offered in response to a contract between the Energy Secretariat of the Province of New Brunswick (Secretariat) and ADI Limited for a study on the "Determination of Supply and Demand of Wood Residues for Energy Generation - Forest Region 2". "Woodlot Service (1978) Limited and Edward S. Fellows served as subcontractors on the project. The study is to be directed to the forestry sector only, since work has already been completed on the availability and allocation of wood residues from the manufacturing sector.

The Forest Region 2 (hereinafter called Region 2) encompasses most of the county of Northumberland and small portions of York, Sunbury and Kent. For this study the region for resource survey includes only Region 2. However, the region considered for potential utilization (as fuel) of the residue includes all of Region 2 and a portion of Regions 1 and 3 (refer to Figure 1 following). The economic transport distance from Newcastle, the assumed centre of Region 2, will be 70 km.

The study involved a detailed on-site examination of many cut-over areas to determine volumes of slash and standing residual trees, the moisture content*, extent of degradation, accessibility and environmental damage, all by age of cuts. Having determined volumes, an assessment was made of methods and costs applicable for the removal of this form of forest residue to roadside and preparation into chip form for use as a fuel. It also investigated the cost of residue extraction from each of the three basic mechanical logging systems, including whole-tree, tree-length and short-wood.

*Moisture contents in this report are given on an oven-dry basis except as otherwise noted.

FIGURE 1: KEY PLAN OF STUDY AREA

This cost has been compared with a "value" for the wood residue fuel as developed for a total of six typical consumers, including:

- a small school;
- a large school;
- a hospital complex;
- a small industrial load;
- a large industrial load (requiring a new wood-fired boiler);
- a large industrial load (having an existing wood-fired boiler);

The "value" of the residue has been determined from:

- capital costs for assets required for handling and combustion of the wood fuel;
- a payback allowance based on periods considered realistic for each type of consumer;
- the incremental increase in operating costs;
- the amount of wood consumed and the oil fuel displaced.

A series of graphs has been prepared to show intersections of "costs" and "values". These points, indicate the limiting distances for transport of the residues at a total cost competitive with the present fuel.

The study was conducted in accordance with the terms of reference as outlined below:

1.1 - establish the economic availability of logging residues by species, form, quantity and location within Region 2, to include the residues from past and current operations and the expected residues generated from future operations. The study is to include nonmerchantable

species, dead and diseased stock and undersize trees--all of which have value as residue.

1.2 - examine the economics of residue extraction from each of three basic mechanical logging systems, namely: whole-tree, tree-length and short-wood (4' and 8').

1.3 - determine the best system for processing the residue into a form suitable for use as a fuel, the preferred location in the harvesting system for the process facilities, and the cost of the prepared residue at a landing of a quality suitable for access by large vans.

1.4 - conduct a literature search of systems currently in use for the extraction, handling and preparation of residue. The review is to address the effect on the environment, such as changes in the nutrient balance as a result of removing materials which are normally left in the forest. It will also examine the possible effect of the residue removal on wildlife habitat, water runoff, fire hazard, damage to regeneration and attack by insects and diseases.

1.5 - it is recognized that a portion of the residue may have higher value-added use/s than fuel. Accordingly, a review will be conducted of other uses to which the residue may be directed which might provide increased benefits to the processor and the Province.

1.6 - examine ways of transporting the prepared residue to an identified user, means of loading and unloading; develop costs for typical transport systems including single-axle and tandem vehicles, as well as vans and railcars should a large consumer be located having suitable facilities for unloading of railcars.

1.7 - determine the best method/s of quantifying the residue as shipped to a consumer including: weight, moisture content, heating value, gradation of material, and extent of noncombustible contaminants.

1.8 - determine the potential market for residue as a fuel within industrial, institutional and commercial establishments, as well as for residential use. Examine current costs of energy generation using fuels other than wood residue, to include: petroleum-based fuels (#2 oil and #6 oil), coal, electric power and propane. The study will also examine the effect that natural gas will have on the use of wood residue given the expected cost structure as developed by the National Energy Program (NEP).

1.9 - develop costs for conversion of existing combustion systems to wood residue use, and costs for new equipment to replace existing or projected systems using fuels other than wood residue. From this, a summary will be prepared to relate costs of wood residue as a fuel compared to other systems for comparable amounts of heat generation.

1.10 -prepare a report of findings incorporating an executive summary and recommendations as to use of wood residue.

SECTION 2

EXECUTIVE SUMMARY

DATA

2. EXECUTIVE SUMMARY - DATA

2.1 The Supply of Forest Residues in Region 2

A major part of this study was a methodical field survey and detailed sampling procedures to determine the quantities of forest residues available in Forest Region 2 (the Miramichi drainage plus some adjacent lands). Initial investigations included areas harvested as long ago as five years; they showed that it would be unwise to try to retrieve logging slash older than three years at most, probably two years. The reasons were that it would be silviculturally harmful, retrieval would be relatively expensive and the available quantities of potential fuel would be much reduced. The rest of the survey concentrated on measuring slash and standing residual trees on one- and two-year-old cut-overs.

The field work demonstrated that, in Region 2, for each 1 000 hectares of typical mature forest harvested, there would be physically available 46 875 metric tonnes (oven-dry basis) of forest residues. The actual moisture content of the material averaged 38 percent (oven-dry basis). Assuming that the average annual harvest in the Region covers 8 000 hectares, the amount of forest residue available each year would be about 375 000 tonnes (oven-dry basis), or 517 500 tonnes at its actual moisture content.

The amount of residue developed during any harvesting operation is not affected by the logging method used, but the location of the "slash" is. In the so-called short-wood and tree-length systems, the tree-top and branches are left on the ground near the stump. In the short-wood system the slash may look as if it were windrowed, but under both systems it is scattered over all the harvested area. In the whole-tree system, entire trees are dragged or carried to a central landing where the tops and

branches accumulate. Trees which are carried are only slightly contaminated with soil and gravel. Slash which is picked off the ground contains the most mineral contaminants. Trees which are dragged to a landing gather a moderate quantity of grit and stones.

2.2 Region 2 Demand for Forest Residue Fuel

Although advances are being made in the design of residential heating-systems for burning chipped wood, problems with fuel delivery and storage as well as high capital costs may restrict this market for chips unless innovative economics are developed. Institutions and large industries such as pulpmills are more likely to be the chief outlets for such fuel.

A census of all schools, hospitals and large and small industries in or near to Region 2 was taken and the amount of oil (the predominant fuel) they burned annually was ascertained. This provided a measure of the regionl energy demand for institutional space heating and industrial steam. For various reasons, it would be impractical for some oil users to switch to wood fuel; however, assuming that 30 percent of oil users would choose the latter fuel, there could be market for 241 000 tonnes per year of forest residues at 80 percent moisture content (80% M.C.), IF it could be delivered at competitive prices. This volume is far below the amount physically available, but not necessarily more than is now economically available.

Consideration was given to coal, electricity, propane and natural gas as alternatives to oil or wood. There is no chance of natural gas being piped into the Region in the near future. The other fuels would be practical and economic options only in special cases.

2.3 Costs of Retrieving Forest Residues

Four studies conducted in three of the Atlantic Provinces provided the data for estimating the costs of retrieving forest residues. These studies included 11 individual projects involving different logging systems and different forest conditions.

The analysis concluded that, with whole-tree harvesting, fuel chips can in most cases be produced in the forest and loaded into vans at costs ranging from $6.25 to $8.50 per tonne at 80% M.C. Low-quality hardwood and mixedwood stands harvested solely for fuel by the whole-tree method can produce chips at costs usually within the range of $18.25 to $24.75 per tonne (80% M.C.). The most costly chips are those resulting from the retrieval of slash and standing residuals in separate operations following the production of industrial wood by the short-wood or tree-length system. The variation in conditions typical of these logging methods entails costs spreading from $27.00 to $36.50 per tonne (80% M.C.). Machines now under development and designed especially for retrieving slash show promise of moderate reductions in costs. Of course, there will always be special circumstances resulting in costs of production above or below the normal ranges.

Where harvested areas are to be reforested by planting, savings in costs of site-preparation of about $125 per hectare are achieved by removal of slash and standing residuals for chipping.

2.4 Competitive Value of Wood Fuel at Roadside

The efficient use of wood fuel entails substantial investments in fuel-storage facilities, fuel-handling equipment and expensive combustors. Furthermore, large installations usually employ more operators than do equivalent oil-fired boilers. The economics of burning wood are optimized when this fuel is used in high-load-factor situations; that is, when the combustor is operated steadily as near to its capacity as possible over as long a period as possible.

To determine the relative "value" of wood-chip fuel vis-à-vis that of oil, all these capital and operating costs must be placed in the equation.

This study analyzed all these financial considerations relating to the use of wood chips as contrasted with burning oil. Calculations were made for scenarios applicable to typical boiler installations in (1) a small school, (2) a large school, (3) a hospital complex, (4) a small industry, (5) a large industry considering changing from oil to wood fuel, and (6) a large industry considering increasing its use of wood fuel in existing facilities.

These analyses determined the relative "values" of wood-chip fuel at a typical institution or plant at which this form of fuel would gain an equal footing with oil -- all economic factors considered. In the case of a small industry typical of the Region, it was found that, even at a "value" of zero, wood cannot compete with oil. In all other cases, wood can be competitive at some price level.

The next step was to calculate trucking costs which, when subtracted from the "value" of wood chips at the point of use, would show their "value" in the forest at any distance up to 70 kilometres away.

Graphs 6.1.1 to 6.1.15 compare these wood-chip "values" with the costs of producing the chips. From them one can estimate whether it would be economically sound for a typical institution or industry in the Region to switch from oil to wood fuel. These graphs show that the chips produced in whole-tree harvesting are often fully competitive with oil, even with quite long truck-hauls. Cutting forest stands exclusively for fuel chips is a practical proposition when the users are small schools; large industries with existing wood-burning facilities and hospitals could use this source of fuel to advantage only within a restricted hauling radius. With conventional methods, chips developed in separate clean-up operations are uneconomic except for small schools and large industries already suitably equipped, and then only if the sources are fairly close.

2.5 Environmental Considerations

Clearing all slash and standing timber from a harvested area virtually eliminates any forest-fire hazard and creates near-ideal conditions for reforestation by planting. It also reduces the risk of insect and disease outbreaks that can be spawned in slash and (arguably) improves the appearance of a harvested area. Most other environmental consequences are mildly negative. It should be stressed that the environmental results of commercial clear-cutting are not addressed here, but only the incremental impacts of removing the resulting residues. These impacts include the exposure of the soil to greater insolation to the detriment of the flora, fauna and moisture content of

the upper soil layers, the removal of mulch and plant nutrients and the greater exposure of the soil to water erosion. On balance, the total removal of slash and residual trees does not favour the natural regeneration of the forest nor, as a generality, does it favour wildlife. However, these impacts are relatively small as compared to the consequences -- good and bad -- of commercial clear-cutting. As in clear-cutting, the effects increase with increasing size of the area involved. Where the soil is very shallow or very wet, the removal of logging residues may be inadvisable or even unacceptable.

Wood smoke contains rather high concentrations of particulates, but is almost entirely free of compounds of sulphur which contribute to the formation of acid precipitation. The storage of damp or wet wood promotes the growth of fungi and the subsequent dispersal of their spores and hyphae into the air. Some people are allergic to these contaminants.

2.6 Wood - The World Demand and Supply

The world demand for forest products is expected to continue its rapid rise. In the developed countries the increase will be for manufactured products; inthe developing countries the greater use wil be for fuel. During the last quarter of this century total world use of wood is expected to rise from 2 511 million cubic metres (m^3) to 3 800 million m^3 -- an increase of 66 percent. The use of wood for industrial purposes only is projected to go up by 87 percent in the same period and this is the sector in which Canada is most concerned.

All the major importers of wood products -- the United States, the United Kingdom, Western Europe and Japan -- are doing their best to increase their own domestic production of wood, but they expect their shortfalls to grow steadily. All these areas are customers of Canada, and most are customers of New Brunswick.

They all anticipate greater importations of wood products from Canada over the coming decades. There are growing doubts that world supplies can continue to support the expanding demands indefinitely. Wood is a most versatile raw material. It is processed into many different structural materials, papers and packaging materials, chemicals and even foodstuffs, and it is a widely distributed source of energy whether used in its natural, solid form or converted into liquid or gaseous fuels.

But aside from its cost or price, wood is not a preferred fuel as compared with other sources of energy; it has a number of shortcomings. On the other hand, it is an outstanding structural material. Not only does it have a high ratio of strength to weight, but it can be harvested and processed with far less energy than the equivalent quantities of most other structural materials.

In terms of the efficient use of energy, the consumption of wood for various classes of end-use may be classified in the following descending order of merit:

1. (Most energy-efficient use) For fibre products and structural products.

2. For fuel when used in its natural forms.

3. For the production of edible products.

4. (Least energy-efficient use) For chemical products, such as methanol, ethanol, phenol and furfural.

In general, it can be said that the higher the cost of energy, the higher the relative value of wood for its most energy-efficient uses and the higher its relative value in comparison to the costs of other more energy-comsuming structural materials.

In terms of the annual allowable cut of "merchantable" timber, there is now in New Brunswick a small, but fast-diminishing surplus of hardwood and an overall shortage of softwood. There is a large and almost unused surplus of forest residues consisting of harvesting "slash" and standing residual trees with little or no present commercial use. In the short term, it would be very desirable, from a silvicultural standpoint, if economically sound ways could be found to use this material for fuel. However, before long this material may well have higher value to the Province as industrial feedstock. This report warns against a long-term commitment to wood fuel which could inhibit preferable developments.

SECTION 3

EXECUTIVE SUMMARY
CONCLUSIONS AND RECOMMENDATIONS

3. EXECUTIVE SUMMARY

3.1 Conclusions

The conclusions of the study, briefly stated, are as follows:

1. The quantity of residue available is estimated to be 375 000 oven-dry tonnes for a yearly harvest area of 8 000 hectares.

2. For a given harvest area, the higher the volume of the original cut, the higher will be the volume of recoverable fuel.

3. Cuts more than two years old rapidly become less suitable for residue recovery operations.

4. The higher heating value of dryer wood chips is partially offset by increased transportation costs due to load size being governed by bulk rather than weight, as moisture content diminishes.

5. Removal of residues is generally seen to have minimal additional negative environmental impact compared to the original cutting operation. The reduction of fire hazard and improvement of replanting conditions tend to balance some negative effects.

6. Detailed evaluation of specific sites for conversion to wood fuel should be undertaken. Refer to Section 6 for particulars.

For the sake of brevity the "Recommendations" are not repeated here - reference section 6.2 following (page 80).

SOMMAIRE EXECUTIF

2e PARTIE

DONNEES RELATIVES AU RESUME

2. RESUME - DONNEES

2.1 L'approvisionnement en déchets de coupe dans la région n°2

La majeure partie de cette étude consistait en une étude sur le terrain méthodique et des procédures d'échantillonage détaillées en vue de déterminer les quantités de déchets de coupe se trouvant dans la région forestière n° 2 (le bassin hydrographique de la Miramichi et quelques terres adjacentes. Les premiers examens portaient sur des régions récoltées jusqu'il y a cinq ans; ils ont démontré qu'il serait imprudent d'essayer de récupérer des rémanents demeureés sur l'assiette de coupe depuis plus de trois ans au maximum, probablement deux ans. Les raisons en sont les suivantes: cela aurait des effets nuisibles sur le plan sylvicole, la récupération serait relativement coûteuse et la quantité de combustible éventuel disponible serait considérablement réduite. Le reste de l'étude a porté sur la mesure des rémanents et des arbres sur pied qui restaient dans des peuplements exploités âgés de un et deux ans.

Les travaux sur le terrain ont démontré que pour chaque 1 000 hectares de forêt type arrivée à maturité et récoltée dans la région n°2, il y aurait 46 875 tonnes métriques (sur une base anhydre) de déchets de coupe. La teneur en humidité réelle des déchets était en moyenne de 38 pour cent (sur une base anhydre). Supposons que la récolte annuelle moyenne de la région englobe 8 000 hectares, la quantité de déchets de coupe obtenus chaque année serait d'environ 375 000 tonnes (sur une base anhydre) ou 517 500 tonnes avec la teneur en humidité réelle.

La méthode d'abattage utilisée n'a aucun effet sur la quantité de déchets de coupe obtenus au cours d'une récolte quelconque, mais elle en a sur l'emplacement des "rémanents". Dans les exploitations dites de bois courts et par fûts entiers, on laisse le faîte de l'arbre et les branches sur le sol près de la souche. Dans le système de bois courts, il se peut que les rémanents semblent former un andain, mais dans les deux exploitations, ils sont éparpillés sur toute la zone récoltée. Dans le système par arbres entiers, les arbres entiers sont traînés ou transportés jusqu'à un dépôt central où les faîtes et les branches s'accumulent. Les arbres transportés ne sont que très peu contaminés par la terre et le gravier. Les rémanents qui sont ramassés du sol contiennent le plus d'agents minéraux contaminateurs. Les arbres traînés jusqu'à un dépôt ramassent une quantité modérée de sable et de roches.

2.2 La demande de la région n°2 en matière de combustible provenant des déchets de coupe

Bien que nous faisions des progrès dans la conception des systèmes de chauffage résidentiels aux copeaux de bois, les problèmes que causent la livraison et l'entreposage, ainsi que les coûts d'immobilisation élevés, peuvent restreindre ce marché pour les copeaux; il faut donc trouver des moyens innovateurs pour rentabiliser cette activité. Les établissements et les grandes industries telles que les usines de pâte ont le plus de chances de servir de débouchés pour un tel combustible.

On a fait le recensement de toutes les écoles, de tous les hôpitaux et de toutes les industries, petites et grandes, situés à l'intérieur ou à proximité de la région n° 2 et on a vérifié la quantité de mazout (le combustion principal) qu'ils utilisaient chaque année. Cela permettait d'évaluer la demande énergétique régionale pour le chauffage des locaux des grands organismes et la production de vapeur aux fins industrielles. Pour diverses raisons, il ne serait pas pratique pour certains utilisateurs de mazout d'adopter le bois comme combustible; cependant, supposons que 30 pour cent des utilisateurs de mazout choisissent ce combustible, il serait possible de vendre 241 000 tonnes de déchets de coupe par année avec une teneur en humididté de 80 pour cent (t.h. de 80%), si le combustible pouvait être livré à un prix concurrentiel. Ce colume est considérablement inférieur à la quantité physiquement disponible, mais il n'est pas nécessairement supérieur à la quantité actuellement disponible sur le plan économique.

On a examiné la possibilité de remplacer le mazout ou le bois par du charbon, de l'électricité, du propane ou du gaz naturel. Aucun gazoduc ne sera installé dans la région avant plusieurs années. Les autres combustibles représentent des solutions de rechange pratiques et économiques seulement dans des cas particuliers.

2.3 Les coûts de récupération des déchets de coupe

Grâce à quatre études effectuées dans trois des provinces de l'Atlantique, des données ont été recueillies pour évaluer les coûts de récupération des déchets de coupe. Ces études comportaient onze différents projets impliquant différentes méthodes d'abattage et conditions forestières.

Pour ce qui est de l'exploitation par arbres entiers, l'analyse a prouvé qu'il était possible dans la plupart des cas de produire des copeaux en forêt et de les charger sur camions à un coût allant de 6,25 $ à 8,50 $ la tonne à 80% de t.h. En récoltant du bois de feuillus de pauvre qualité et des peuplements mélangés grâce à la méthode d'exploitation par arbres entiers pour en faire du combustible seulement, il est possible de produire des copeaux à un coût variant habituellement entre 18,25 $ et 24,75 $ la tonne (t.h. de 80%). Les copeaux les plus coûteux sont ceux qui proviennent de la récupération des rémanents et des résidus sur pied de différentes exploitations, suite à la production de bois industriel selon le système d'exploitation de bois courts ou par fûts entiers. La variation des conditions propres à ces modes d'exploitation occasionne des coûts se situant entre 27 $ et 36,50 $ la tonne (t.h. de 80%). Grâce aux machines construites actuellement et conçues spécialement pour la récupération des rémanents, il devrait être possible de réduire ces coûts modérément. Bien entendu, il existera toujours des circonstances particulières lors desquelles les coûts de production seront supérieurs ou inférieurs aux taux habituels.

Lorsqu'une région récoltée doit être reboisée artificiellement, il est possible de réaliser des économies d'environ 125 $ par hectare pour la préparation du terrain en enlevant les rémanents et les résidus sur pied pour en faire des copeaux.

2.4 Valeur concurrentielle du combustible provenant du bois débardé

L'utilisation efficace du bois comme combustible nécessite des investissements considérables dans les domaines suivants: les installations d'entreposage du combustible, le matériel de manutention du combustible et les dispositifs appelès à le brûler. En outre, il faut habituellement un plus grand nombre d'ouvriers pour faire fonctionner de grandes installations que pour faire fonctionner des chaudières au mazout équivalentes. La rentabilité de la combustion du bois est accrue si ce dernier est utilisé lorsque le coefficient d'utilisation est élevé, c'est-à-dire lorsque le dispositif de brûlage fonctionne sans arrêt le plus près possible de sa capacité, et ce pendant le plus longue période possible.

Pour déterminer la "valeur" relative des copeaux de bois par rapport à celle du mazout, il faut tenir compte de tous ces coûts d'immobilisation et d'exploitation.

Cette étude analyse toutes les considérations d'ordre financier relatives à l'utilisation des copeaux de bois par opposition à la combustion du mazout. Des calculs ont été effectués relativement à l'installation d'une chaudière type dans des endroits différents: (1) une petite école, (2) une grande école, (3) un hôpital, (4) une petite industrie, (5) une grande industrie envisageant d'employer du bois à la place du mazout, et (6) une grande industrie envisageant d'augmenter son taux d'utilisation du bois comme combustile dans ses installations existantes.

Ces analyses ont déterminé les "valeurs" relatives des copeaux de bois dans un établissement ou une usine type dans laquelle cette forme de combustible deviendrait aussi importante que le mazout - en considérant tous les facteurs économiques. Dans le cas d'une petite industrie type de la région, il est apparu que même à une "valeur" de zéro, le bois ne peut concurrencer le mazout. Dans tous les autres cas, le bois peut être concurrentiel à un certain prix.

L'étape suivante consistait à calculer les coûts du transport par camion, qui, une fois soustraits de la "valeur" des copeaux de bois au point d'utilisation, indiqueraient leur "valeur" dans la forêt à une distance n'excédant pas 70 kilomètres.

Les graphiques 6.1.1 et 6.1.15 permettant de comparer les "valeurs" de ces copeaux de bois et leurs coûts de production. A partir de ces graphiques, il est possible de déterminer s'il serait rentable pour un établissement ou une industrie type de la région d'utiliser du bois au lieu du mazout comme combustible. Ils indiquent que les copeaux produits dans une exploitation par arbres entiers font souvent une grande concurrence au mazout, même lorsque le transport par camion est très long. Lorsque les utilisateurs sont de petites écoles, il est recommandé de couper des peuplements pour la production exclusive de copeaux de bois; les grandes industries dotées d'installations de combustion du bois et les hôpitaux pourraient tirer avantage de cette source de combustible seulement à l'intérieur d'un rayon de débardage restreint. Avec les méthodes conventionnelles, les copeaux produits lors de différents travaux de nettoyage s'avèrent peu rentables, sauf dans le cas des petites écoles et des grandes industries déjà bien équipées, et également à la condition que les sources soient assez proches.

2.5 Considérations d'ordre environnemental

L'enlèvement de tous les rémanents et des arbres sur pied d'une zone récoltée élimine pratiquement tout risque d'incendie et crée des conditions presque idéales pour le reboisement artificiel. Il réduit également les risques d'apparition de maladies et d'insectes qui peuvent se développer dans les rémanents et (selon certains) il permet d'améliorer l'apparence d'une région récoltée. La plupart des autres conséquences sur le plan de l'environnement sont légèrement négatives. Il faudrait préciser que les résultats d'une coupe à blanc commerciale sur ce plan ne sont pas examinés ici, mais seulement les effets d'accroissement de l'enlèvement des résidus. Ces effets comprennent l'exposition du sol à un taux plus élevé d'insolation au détriment de la flore, de la faune et de la teneur en humidité des couches supérieures du sol, l'enlèvement du paillis et des éléments nutritifs des plantes et une plus grande exposition du sol à l'érosion de l'eau. Tout compte fait, l'enlèvement total des rémanents et des arbres résiduels ne favorise pas la régénération naturelle ni, en règle générale la faune. Toutefois, ces effets sont relativement minimes comparativement aux conséquences -- bonnes et mauvaises -- des coupes à blanc commerciales. Comme dans le cas des coupes rases, le nombre d'effets augmente selon la superficie de la zone en question. Lorsque le sol est très peu profond ou très humide, l'enlèvement des déchets de coupe peut être à déconseiller ou même inacceptable.

La fumée de bois contient des concentrations plutôt élevées de particules colloïdales, mais ne comprend à peu près pas de composés soufrés qui contribuent à la formation des pluies acides. L'entreposage du bois humide ou mouillé favorise la croissance de champignons et la dispersion ultérieure des spores et des hyphes dans l'air. Certaines personnes sont allergiques à ces contaminants.

2.6 Bois - La demande et la provision mondiales

La demande mondiale en matière de produits forestiers devrait continuer d'augmenter rapidement. Dans les pays industrialisés, c'est la demande de produits fabriqués qui se multipliera, tandis que les pays en voie de développement feront une plus grande utilisation des combustibles. Au cours du dernier quart du siècle, le taux total d'utilisation mondiale du bois devrait passer de 2 511 millions de mètres cubes (m^3) à 3 800 millions m^3 soit une augmentation de 66 pour cent. Le taux d'utilisation du bois à des fins industrielles seulement, et c'est là le secteur dont le Canada se préoccupe le plus, devrait s'accroître de 87 pour cent pendant la même période.

Tous les principaux importateurs de produits forestiers, les Etats-Unis, le Royaume Uni, l'Europe de l'ouest et le Japon, font de leur mieux pour augmenter leur propre production de bois, mais ils s'attendent que leurs provisions diminuent de façon régulière. Toutes ces régions sont des clients du Canada, et la plupart d'entre elles sont clientes du Nouveau-Brunswick. Elles prévoient toutes importer plus de produits forestiers du Canada au cours des prochaines décennies. On doute de plus en plus que les provisions mondiales puissent continuer indéfiniment à satisfaire les demandes croissantes. Le bois est la matière brute la plus souple. Il est transformé en différents matérieux de construction, en papiers et en matériel d'emballage, ainsi qu'en produits chimiques et même en produits alimentaires. Il représente une source d'énergie largement répartie qu'il soit utilisé dans sa forme solide naturelle ou encore sous forme de liquides ou combustibles gazeux.

Mais à part son coût, le bois n'est pas un combustible privilégié par rapport aux autres ources d'énergie; il présente un certain nombre d'imperfections. D'un autre côté, il s'agit d'un matériau de construction hors pair. En plus du rapport élevé entre sa résistance et son poids, il peut être récolté et transformé au moyen d'une quantité d'énergie considérablement moindre que les quantités équivalentes de la plupart des autres matériaux de construction.

En termes d'utilisation efficace de l'énergie, la consommation de bois pour diverses catégories d'usages finals peut être classifiée dans l'ordre d'importance suivant:

1. (Usage à plus haute efficacité énergétique) Pour les produits ligneux et les produits de construction.
2. Pour combustible lorsqu'il est utilisé dans sa forme naturelle.
3. Pour la production de produits alimentaires.
4. (Usage à moindre efficacité énergétique) Pour les produits chimiques tels que l'alcool méthylique, l'éthanol, le phénol et le furfural.

En général, on peut dire que plus le coût de l'énergie est élevé, plus la valeur relative du bois est élevée pour ses usages à plus haute efficacité énergétique et en comparaison aux coûts d autres matérieux de construction consommant de l'énergie.

En termes d'allocation annuelle relative à la coupe de bois "commercialisable", le Nouveau-Brunswick possède actuellement un petit excédent de bois de feuillus, qui s'épuise rapidement, et il connaît une pénurie générale de résineux. La province dispose d'un excédent considérable et presque inutilisé de déchets de coupe se composant de "rémanents" et d'arbres sur pied résiduels qui sont très peu ou ne sont pas du tout commercialisés. Actuellement a court terme, il serait préférable, du point de vue sylvicole, de trouver des moyens rentables pour utiliser ces matériaux comme combustible. Cependant, à brève échéance, ces matières pourraient facilement avoir une plus grande valeur pour la province que les fourrages industriels. Ce rapport ne recommande pas une utilisation à long terme du bois comme combustible car cela pourrait entraver la découverte de meilleures solutions.

3e PARTIE

RESUME

CONCLUSIONS ET RECOMMANDATIONS

3. RESUME

3.1 Conclusions

En résumé, les conclusions de cette étude sont les suivantes:

1. La quantité de déchets de coupe disponible est évaluée à 375 000 tonnes anhydres en ce qui concerne la récolte annuelle d'un terrain de 8 000 hectares.
2. Pour une aire de récolte donnée, plus le volume de la coupe originelle est élevé, plus le volume du combustible récupérable le sera.
3. Les coupes effectuées depuis plus de deux ans deviennent rapidement moins propices à la récupération des déchets de coupe.
4. Au fur et à mesure que la teneur en humidité diminue, le pouvoir calorifique plus élevé des copeaux de bois plus secs est compensé en partie par l'augmentation des coûts du transport en raison de l'importance du chargement qui dépend alors, du volume plutôt que du poids.
5. En général, on considère que l'enlèvement des déchets de coupe a très peu d'effets négatifs additionnels sur l'environnement comparativement à la coupe originelle. La réduction des risques d'incendie et l'amélioration des conditions de replantation ont tendance à compenser certains effets négatifs.
6. Il faudrait entreprendre l'évaluation détaillée d'emplacements particuliers à des fins d'adoption du bois comme combustible. Se référer à la partie 6 pour avoir plu s de détails à ce sujet.

Pour des raisons de place, les "recommandations" ne sont pas présentées de nouveau ici; se référer à la partie 6.2 suivante (page 80).

SECTION 4

REGIONAL FUEL OPTIONS EMPHASIZING FOREST RESIDUES

4 REGIONAL FUEL OPTIONS EMPHASIZING FOREST RESIDUES

4.1 Regional Supply of Forest Residues

In order to properly approach the question of the economic availability of logging residues within Region 2, it was first necessary to quantify the supply of these residues. This required an analysis of the harvest areas within the Region; to first categorize them and then sample them for the amount of residue present. The sample was then used to indicate the total potential of residue supply in the Region.

4.1.1 Data Collection

The New Brunswick Department of Natural Resources maintains a record of cuts for each year within the Province. The location of cuts is determined from aerial photographs usually taken during the winter following harvesting. This information is compiled on base maps.

The first step was to transfer these cut areas by year to forest type maps. These maps show forest types as determined from aerial photo interpretation and allow the determination of the forest type prior to harvesting (see Appendix 4.1.1 for explanation of classification system). The classification used to describe the forest type is quite complicated, but it was decided that only the cover type (either softwood (S), softwood-hardwood (SH), hardwood-softwood (HS) or hardwood (H)) and the volume-class were elements that would have the greatest effect on determining the amount of residue left after harvesting. These two elements along with the year of the cut were combined to form a classification by which all cuts could be identified and took the form of: Cover Type, Cut-Age, Volume-Class. An example of this classification is S 2 5 where the cut originated from a softwood cover type, is two years old and originated from

a 'five' volume-class. The method of harvesting was thought important, but it was a difficult factor to determine in advance since it was not part of the records kept. However, it was decided to note these factors after a specific cut had been visited for sampling.

With this system in mind, all cuts were transferred to forest type maps, their area was determined, and their classification was recorded by map sheet. Numerous cuts from this record had to be eliminated because they had been site-prepared and either planted or scheduled for planting. These sites would definitely not be economically available since any residue collection scheme would destroy the plantation and the investment in it.

The final result of this effort was a tabulation of all cuts within Region 2 by cut classification and area. This summary was by no means absolutely accurate since it is only concerned with harvest operations on Crown Land, but with two-thirds of the harvested volume in the Region coming from the Crown Lands, they at least give the trend in harvesting practices by cut classification.[1]

After an initial field visit, it was decided that no cuts older than five years would be examined. Beyond this age not only is the residue material badly decomposed, but is also deeply entangled in bushes and regeneration that has established since the harvest. The available resource is a constantly diminishing one either through consumption or through decay and deterioration. Standing residuals might be available for as long as ten years following logging before they become inaccessible through unacceptable damage to regeneration or they become useless.

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[1]Anonymous, "Timber Utilization Survey". Department of Natural Resources, Fredericton, New Brunswick, 1980.

Down timber and logging slash more than five years old is almost certainly not worth trying to salvage, and, even if this were not so, any attempt to collect it would cause excessive damage to reproduction.

Sampling within each of the cut classifications was necessary, but, before the total sample was distributed, it was decided to conduct a limited first-stage sampling to test for trends within the population of cuts available. It was arbitrarily decided to sample two cuts within each of the two-year-old softwood categories within each of five (5) volume-classes, thus testing trends between volume-classes. Two cuts for each of five cut-ages would also be sampled within softwood cuts of a 'five' volume-class to test trends between cut-ages. The original plan was to sample a total of eighteen cuts. However, because no cuts existed in the lowest volume-class and because it seemed advantageous to redistribute these samples and to sample additional nearby cuts, a total of 21 cuts were sampled in the final analysis.

Within each of these cuts, plots were established and the amount of residue on each was weighed. Green subsamples were taken and later oven-dried to determine their moisture content.

Each plot was circular and had a radius of one metre. The boundary of the plot was marked on the ground and the slash with orange paint and the slash within the circle was severed from the surrounding material with a chain saw.

The slash on the plot was loaded onto a tarpaulin and raised to a hanging scale supported by a tripod. The plot weight was recorded and a portion of the plot material was bagged for later moisture content determination. Though the number of plots per cut varied depending upon the size of the cut in question, a

total of 88 plots were established for an average of 4.2 plots per cut. In addition to the plot weight, a tally of all standing residuals was recorded by diameter class and species along a line connecting the plot centers within a given cut.

The results of the first-stage sample are given in Table 4.1.1 which shows the weighted-average weight of residue in oven-dry tonnes per hectare on cuts of a softwood cover-type by cut-age and volume-class.

Table 4.1.2 shows the weighted average residual volume per hectare by cut-age and volume-class as determined from the first- stage sample.

In Table 4.1.3 the weighted average total theoretical slash weight is shown by cut-age and volume-class. This is determined by deducting the merchantable volume from the standing residual volume, converting that volume to weight by using average specific gravity figures for various species in Region 2 and adding that weight to the actual residue weight as determined through sampling. This was done so that all cut classes could be compared on the same basis, i.e., as if each cut sampled had in fact been "clear cut".

The results of this investigation are illustrated in Graphs 4.1.1 and 4.1.2 which plot the results in the preceding Tables. The results are as might be expected. In Graph 4.1.1 the amount of residue increases with volume-class, i.e., the greater the volume of merchantable material on a given site before harvesting, the greater the residue material after harvesting. In Graph 4.1.2 the weight of residue decreases with age, i.e., the older the slash, the more decomposed it is and consequently the less it weighs. The trends shown in Graph 4.1.2 are interesting from another point of view. Whereas one-year-old slash has a weight of approximately 50 tonnes per hectare, four- and five-year-old slash has a weight of only approximately 25 tonnes

VOLUME CLASS	CUT AGE (YEARS) 1	2	3	4	5
1					
2		7			
3		37			
4		41			
5	52	48	29	25	27

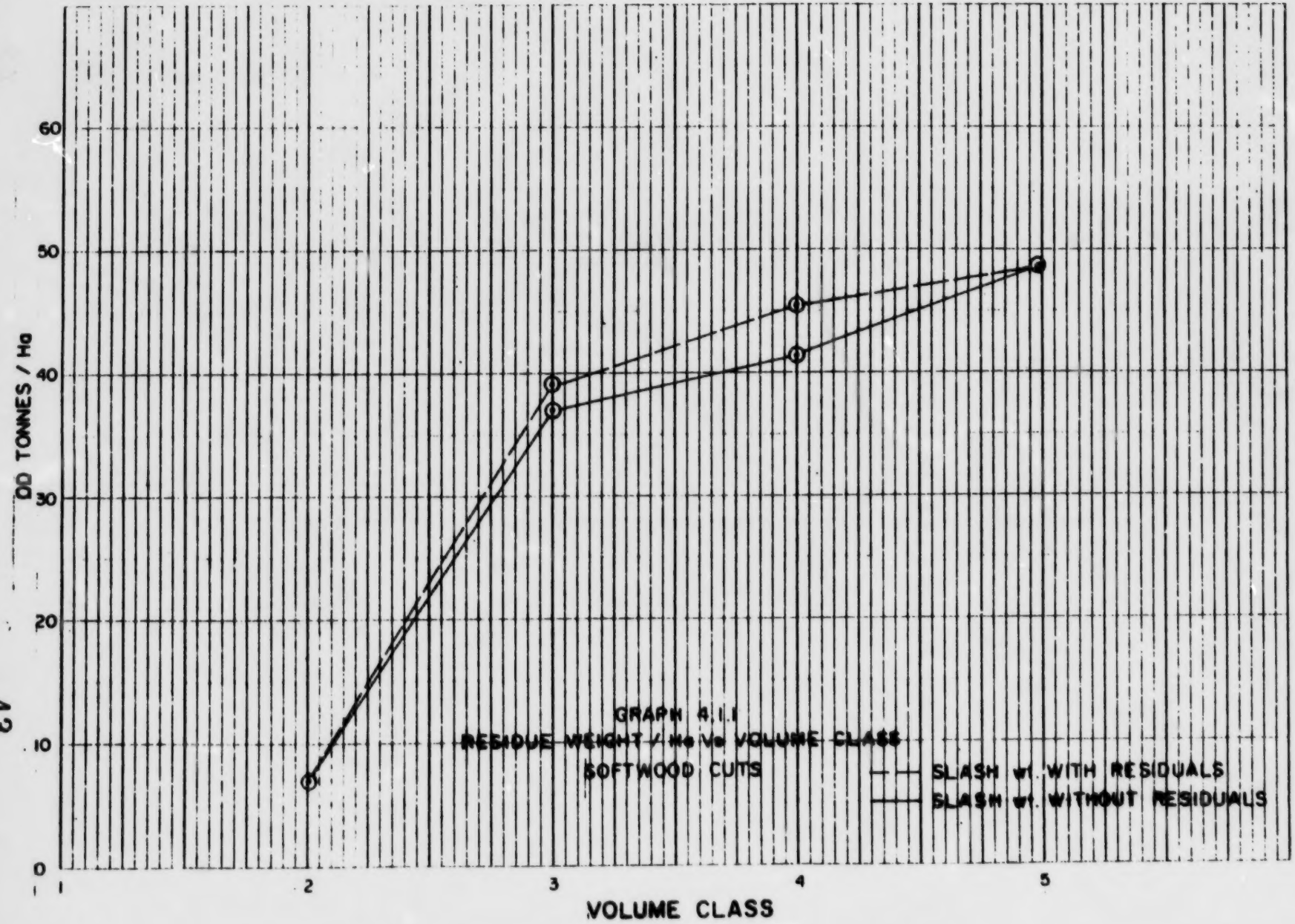
TABLE 4.1.1 : AVERAGE SLASH WEIGHT (OVEN DRY TONNNES PER HECTARE) FOR SOFTWOOD CUTS BY AGE AND VOLUME CLASS. (ALL AVERAGES ARE WEIGHTED BY CUT AREA).

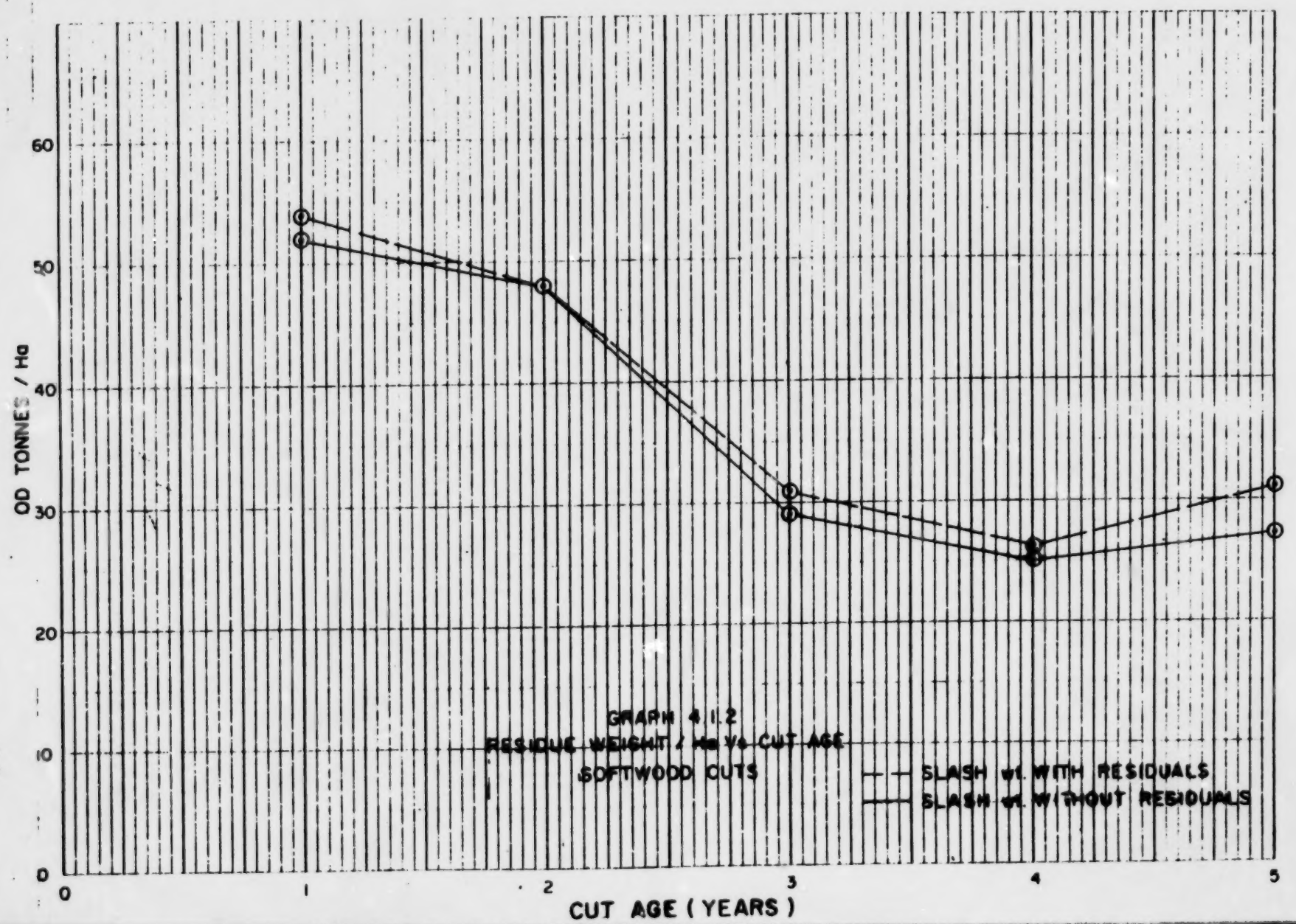
VOLUME CLASS	CUT AGE (YEARS) 1	2	3	4	5
1					
2		2			
3		17			
4		6			
5	13	1	11	5	28

TABLE 4.1.2 : AVERAGE RESIDUAL VOLUME (CUBIC METRES PER HECTARE) FOR SOFTWOOD CUTS BY AGE AND VOLUME CLASS. (ALL AVERAGES ARE WEIGHTED BY CUT AREA).

VOLUME CLASS	CUT AGE (YEARS) 1	2	3	4	5
1					
2		7			
3		39			
4		45			
5	54	48	31	26	31

TABLE 4.1.3 : THEORETICAL AVERAGE TOTAL SLASH WEIGHT (OVEN DRY TONNES PER HECTARE) FOR SOFTWOOD CUTS BY AGE AND VOLUME CLASS. (ALL AVERAGES ARE WEIGHTED BY CUT AREA).


60
50
40
30
20
10
0
OD TONNES / Ha
1
2
3
4
5
VOLUME CLASS
GRAPH A.1.1
RESIDUE WEIGHT / Ha Vs VOLUME CLASS
SOFTWOOD CUTS
SLASH wt. WITH RESIDUALS
SLASH wt. WITHOUT RESIDUALS


OD TONNES / Ha
60
50
40
30
20
10
0
0
1
2
3
4
5
CUT AGE (YEARS)
GRAPH 4.1.2
RESIDUE WEIGHT / Ha Vs CUT AGE
SOFTWOOD CUTS
SLASH wt. WITH RESIDUALS
SLASH wt. WITHOUT RESIDUALS

per hectare. In other words, one would require twice the area of four- and five-year-old slash to harvest an amount equal to that available from a one-year-old cut, other factors being equal. The data indicate that the weight of slash from two- and three-year-old cuts is less than one-year-old cuts, but the decrease, especially in two-year old cuts, is not as drastic as with the four- and five-year-old cuts.

For these reasons it was decided that four- and five-year-old cuts would be omitted from further analysis. In addition to the great decrease in weight affecting these cuts, the slash present is more difficult to gather because of its entanglement in advance growth and there is always the danger of disrupting the growth of any regeneration of commercial species, that would be well established after four to five years, during the slash-gathering process. By eliminating these cuts, greater emphasis could be placed on the more recent cuts which, from this preliminary analysis, showed the most promise.

The second-stage sampling was further modified by increasing the sampling rate on one-year-old cuts. Again the initial data indicated that these would be the most important in that they would produce the greatest amount of slash on a given area. Consequently, cuts selected for the second-stage sample were chosen randomly by map sheet number and cut number with 80% of the sample chosen being one-year-old cuts and the balance distributed evenly between two- and three-year-old cuts. Within each cut-age the sample was distributed proportionately according to the number of hectares within any given cut classification. Five plots, each circular, and with a one-metre radius, were established in each cut with green subsamples taken for later moisture content determination as in the first-stage sample. In the final analysis 64 cuts were sampled and with the addition of the original 16 cuts of one to three years in age

from the first-stage sample, information from a total of 80 cuts was available for analysis. The data from these sampled cuts are listed in Appendix 4.1.2.

As in the first-stage sample, Table 4.1.4 shows the weighted-average weight of residue in oven-dry tonnes per hectare on all cuts by cover-type, cut-age and volume-class.

Table 4.1.5 shows the weighted average residual volume per hectare by cover-type, cut-age and volume-class and Table 4.1.6 shows the weighted average total theoretical slash weight by these same parameters.

The photographs in Appendix 4.1.3 show typical cuts that were sampled and related harvesting equipment.

4.1.2 Potential Supply

The results of the final sampling reinforced the conclusions drawn from the first-stage sample, namely that:

1. the weight of residue material increases with increasing precut volume class,
2. the weight of residue material decreases with increasing age of cut.

These conclusions are particularly evident in the overall results as illustrated in Graphs 4.1.3 and 4.1.4, but, due to small sample-size, they are less evident when the data are examined in detail. For example, these overall trends are quite evident when the data for softwood cover type are plotted individually (Graph 4.1.5), but less so when plotted for hard-wood-softwood cover-types (Graph 4.1.6) because the sample size was so small. Overall slash weight averaged 43 oven-dry tonnes per hectare. Moisture content varied from a high of 81% to a low 15%, but averaged 38% overall on an oven-dry basis.

VOL CL.	COVER TYPE & CUT AGE (YEARS)																	
	S1	S2	S3	SH1	SH2	SH3	HS1	HS2	HS3	H1	H2	H3
1																		
2		12	25			19												
3	24	30	21	71	28	16		23	19		24							
4	33	35	21	32	49	12	18	21	39		30							
5	56	50	38	37	65	28	38	25	30	23	39	11						

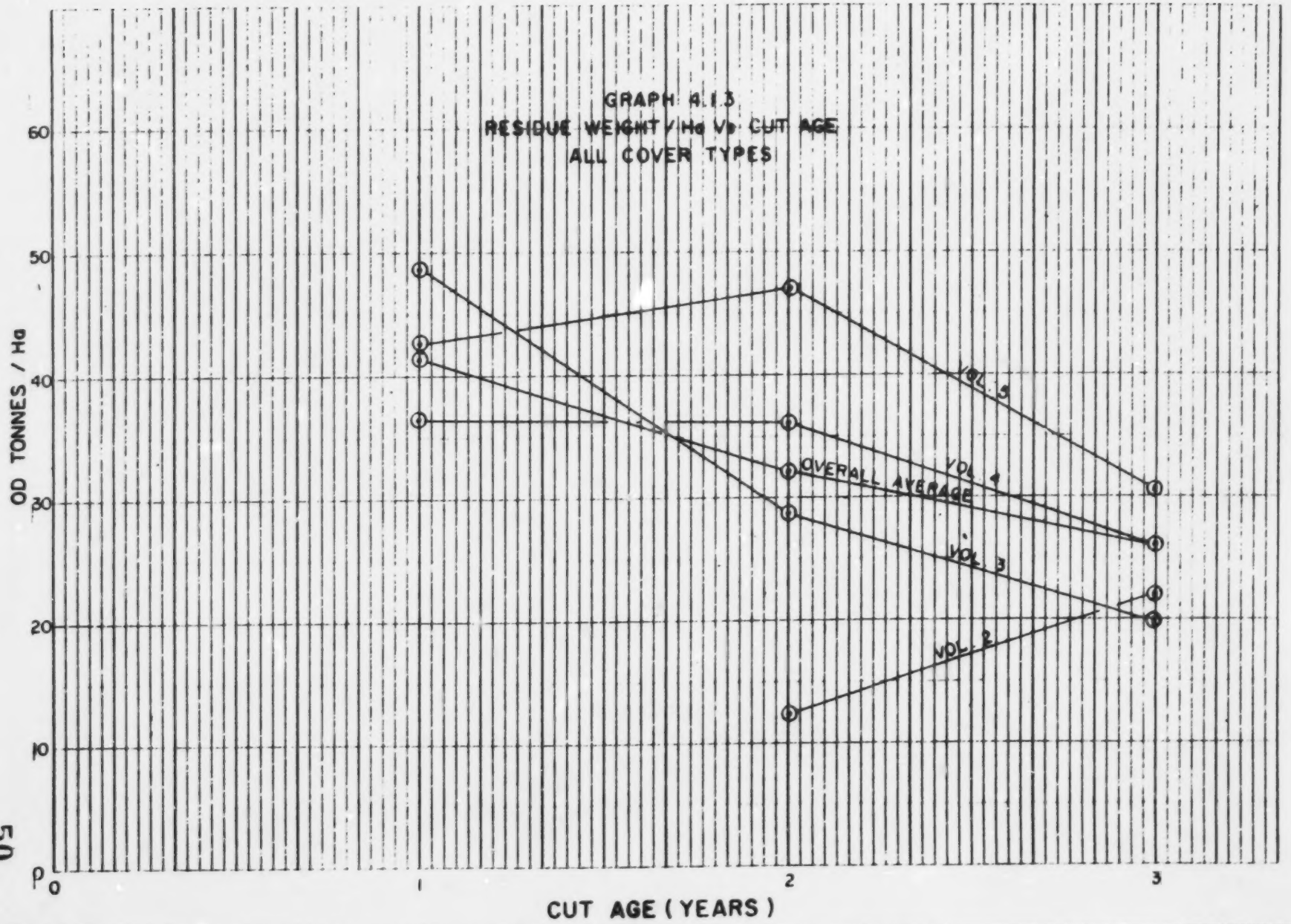
TABLE 4.1.4 : AVERAGE SLASH WEIGHT (OVEN DRY TONNES PER HECTARE) FOR ALL CUTS BY AGE AND VOLUME CLASS.
(ALL AVERAGES ARE WEIGHTED BY CUT AREA).

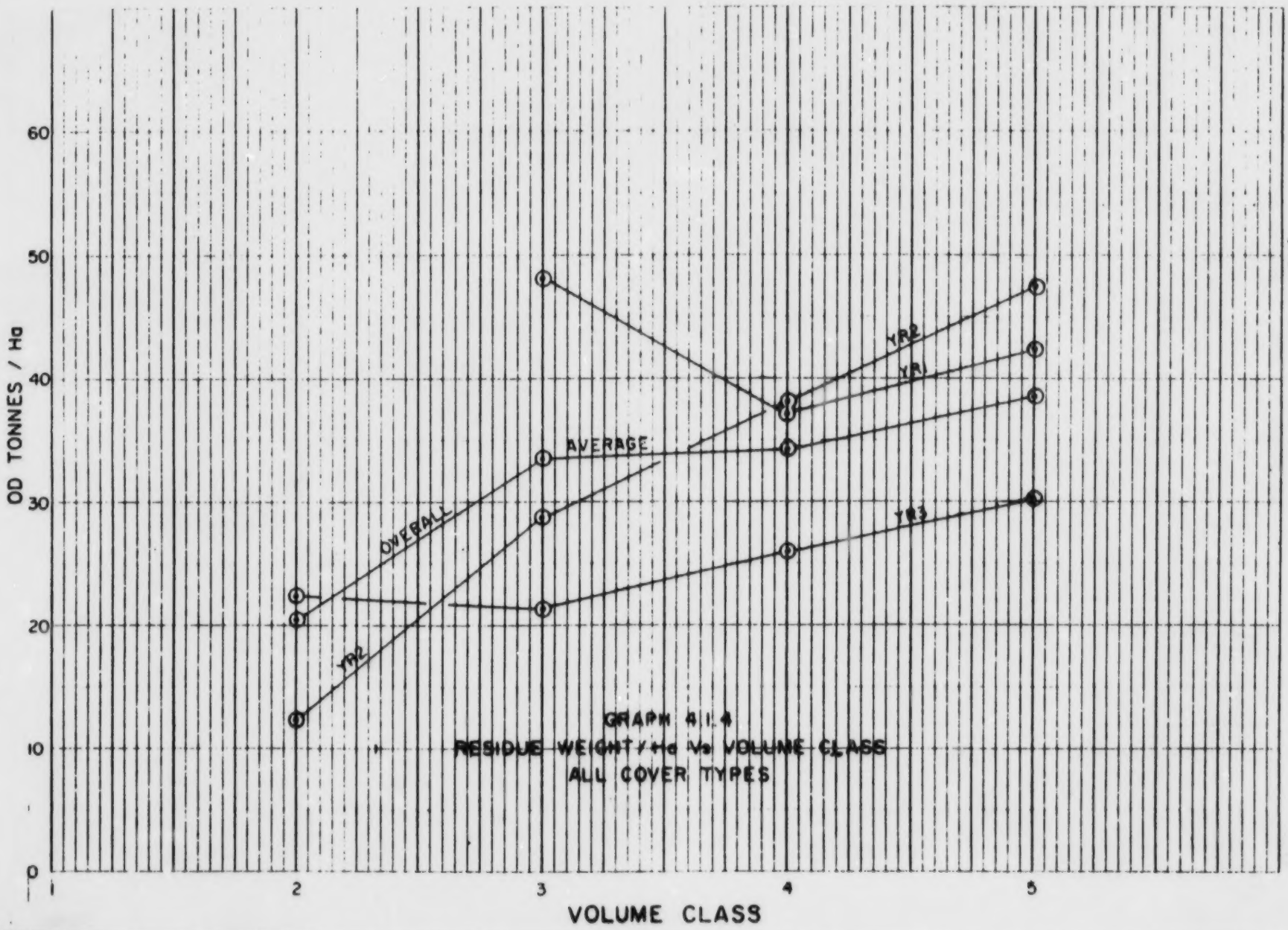
VOL CL.	COVER TYPE & CUT AGE (YEARS)																	
	S1		S2		S3		SH1		SH2		SH3		HS1		HS2		HS3		H1		H2		H3	
1																								
2			2		0						2													
3		1		8		3		2		14		28				23		19				1		
4		19		23		6		38		17		23		96		44		15				7		
5		18		2		8		24		1		2		39		25		43		2		42		0

TABLE 4.1.5 : AVERAGE RESIDUAL VOLUME (CUBIC METRES PER HECTARE) FOR ALL CUTS BY AGE AND VOLUME CLASS.
(ALL AVERAGES ARE WEIGHTED BY CUT AREA).

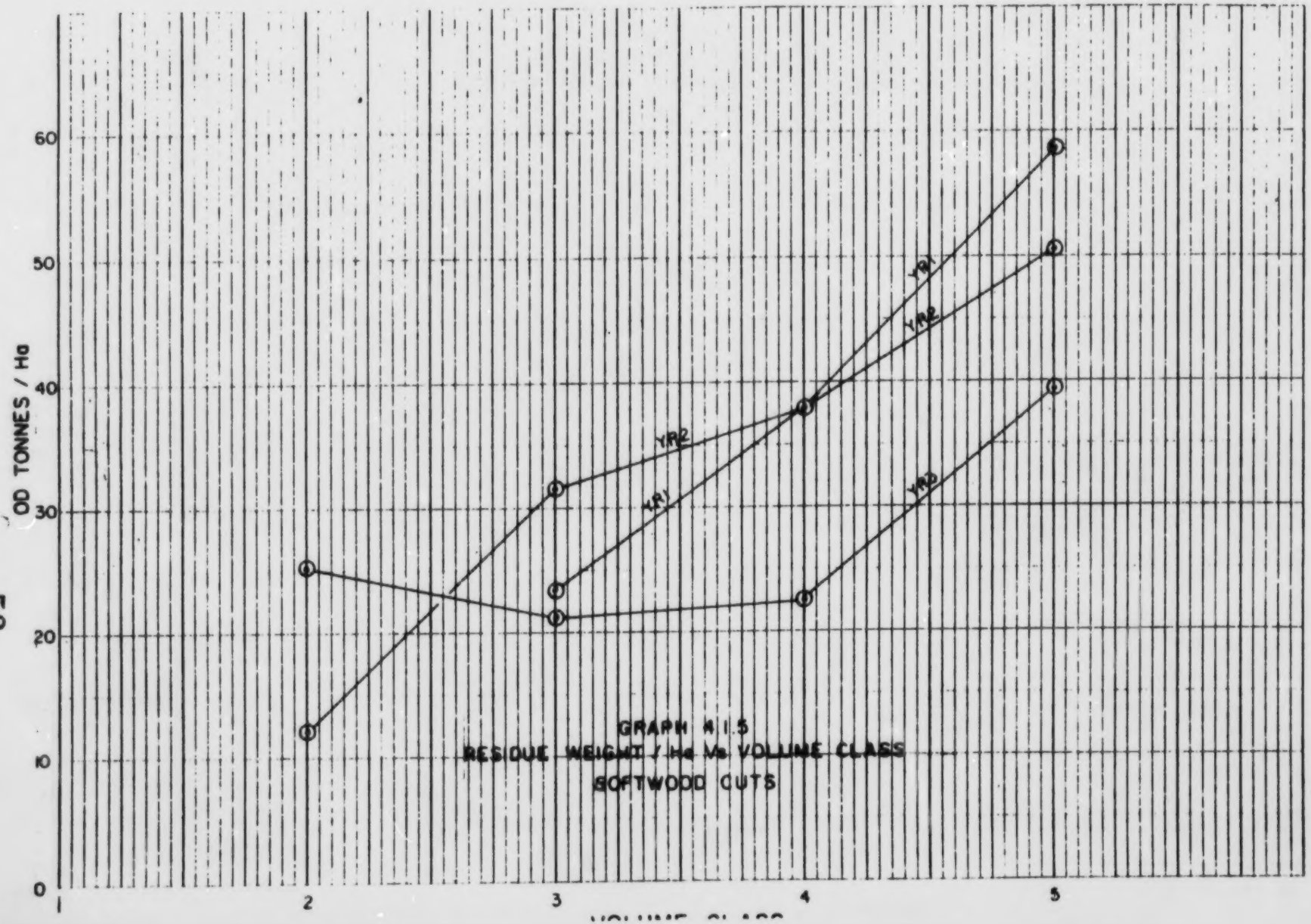
VOL CL.	COVER TYPE & CUT AGE (YEARS)																	
	S1		S2		S3		SH1		SH2		SH3		HS1		HS2		HS3		H1		H2		H3	
1																								
2			12		25						19													
3		24		31		21		71		30		20				32		20			25			
4		37		38		21		39		53		15		36		30		41			32			
5		59		50		39		42		65		28		46		31		42		23		46		11

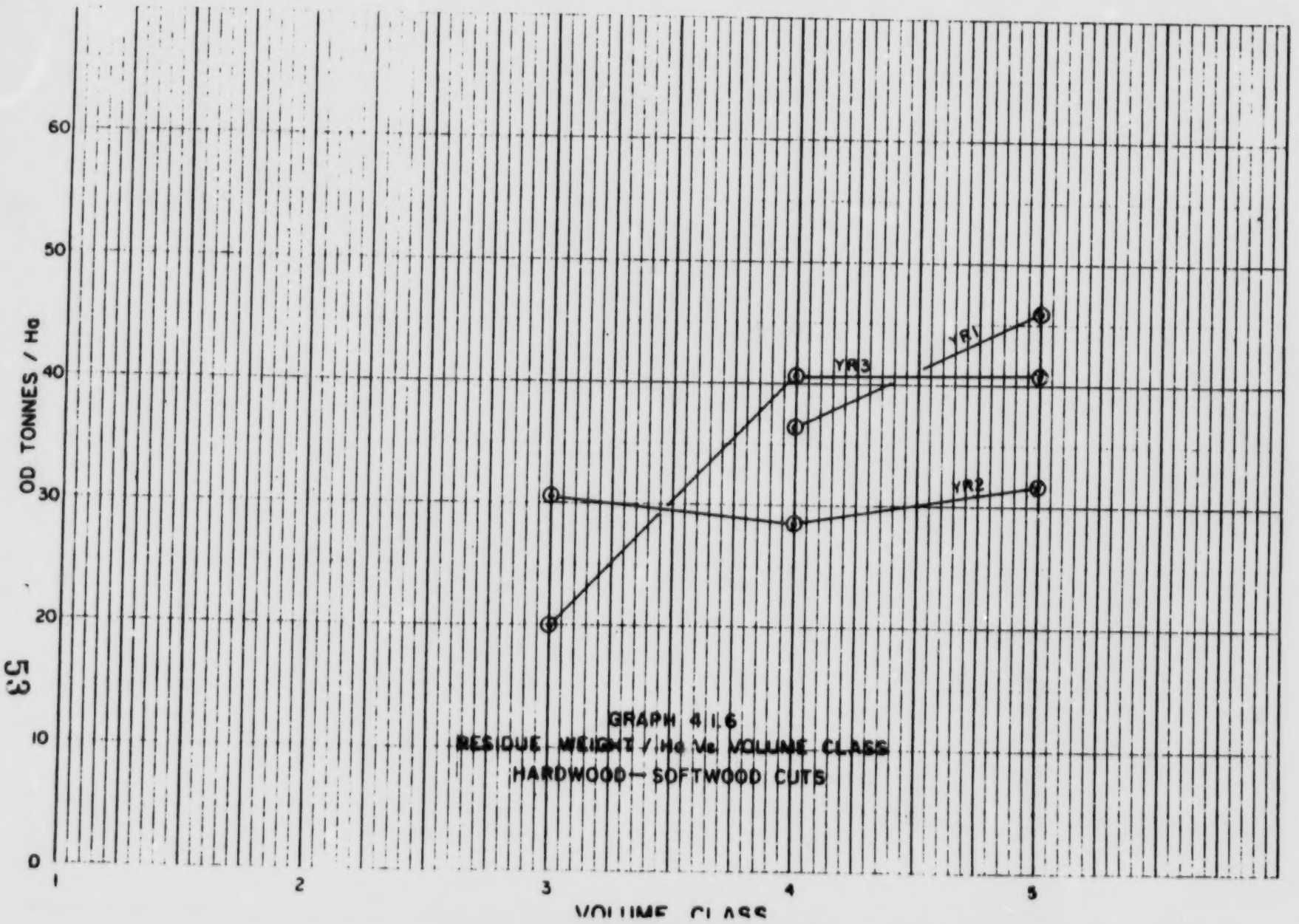
TABLE 4.1.6 : THEORETICAL AVERAGE TOTAL SLASH WEIGHT (OVEN DRY TONNES PER HECTARE) FOR ALL CUTS BY AGE AND VOLUME CLASS. (ALL AVERAGES ARE WEIGHTED BY CUT AREA).


GRAPH A.1.3
RESIDUE WEIGHT / Ha Vs CUT AGE
ALL COVER TYPES
OD TONNES / Ha
60
50
40
30
20
10
0
1
2
3
CUT AGE (YEARS)
VOL. 5
VOL. 4
OVERALL AVERAGE
VOL. 3
VOL. 2



GRAPH A1.4
RESIDUE WEIGHT / Ha Vs VOLUME CLASS
ALL COVER TYPES


OD TONNES / Ha
60
50
40
30
20
10
0
1
2
3
4
5
YR1
YR2
YR2
YR1
YR3
GRAPH A1.5
RESIDUE WEIGHT / Ha Vs VOLUME CLASS
SOFTWOOD CUTS



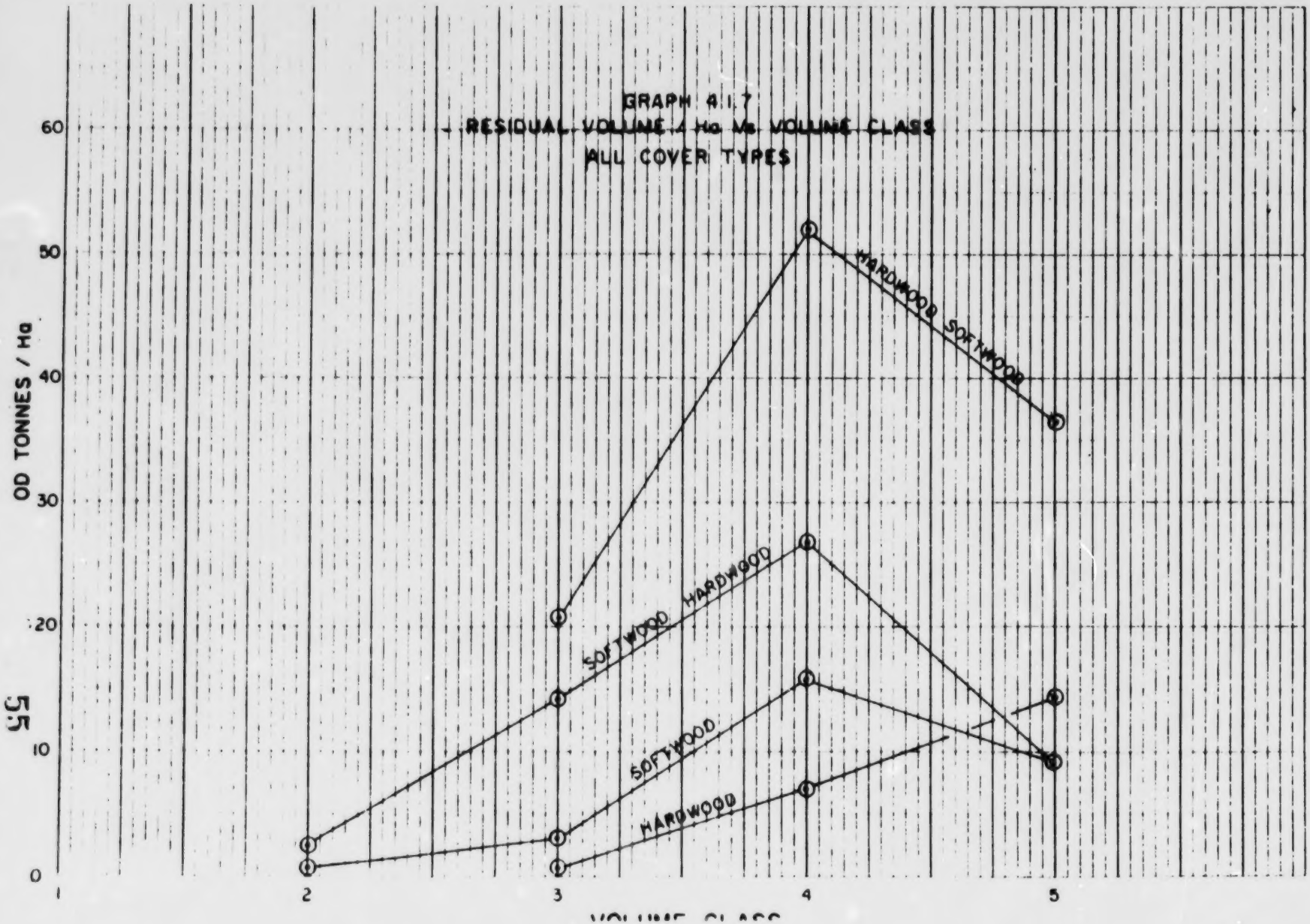
GRAPH 4.11.6
RESIDUE WEIGHT / Ha Vs. VOLUME CLASS
HARDWOOD — SOFTWOOD CUTS

As expected, residual volume increased with prior stand volume-class as shown in Graph 4.1.7. The trends between cover types are less clear, but there are generally more residuals on hardwood-softwood cuts than on softwood-hardwood cuts. Since the demand for softwood species is greater than the demand for hardwood species in Region 2, this is an expected result.

With this demand picture, it is clear that there would still be fewer residuals on softwood cover types. However, hardwood cover types have the lowest residual volume of all cover-types examined. This may seem strange at first, but is explainable by the fact that these pure hardwood stands were most likely harvested by a panelboard manufacturer in the Region. Since their product is a flakeboard they would completely clear-cut stands with no concern for species or quality, thus leaving few residuals.

Overall, there was an average of 16 m^3/ha of standing residuals on all of the cuts examined. This represents eight oven-dry tonnes per hectare of biomass material. Examined more closely, it will be seen that the residual volume varies greatly from no residuals to just less than 100 m^3/ha. Some of the cuts with a high volume of residuals remaining are scheduled for a follow-up cut that would remove merchantable material at a later date when markets improve. Consequently this material would not be available for chip production, and so those cuts were removed from the sample. Once this was done, it was found that 20% of the cuts examined had volumes of 35 m^3/ha or more and in fact averaged 47 m^3/ha. This represented 19 oven-dry tonnes per hectare.

The total amount of residue available per hectare then is the sum of the weight of residue already on the ground plus the weight of the available standing residuals.


GRAPH 4.1.7
RESIDUAL VOLUME / Ha Vs VOLUME CLASS
ALL COVER TYPES
OD TONNES / Ha
60
50
40
30
20
10
0
1
2
3
4
5
HARDWOOD SOFTWOOD
SOFTWOOD HARDWOOD
SOFTWOOD
HARDWOOD

After the review of cut mapping for Region 2, it was found that there were approximately 6 000 hectares of cuts on Crown Land in 1981 and approximately 7 500 hectares in 1980. If, as stated previously, approximately two-thirds of the harvested volume in Region 2 originates on Crown Land, there is approximately 9 000 hectares total harvest in the Region each year. This figure should be reduced to reflect those areas that have poor access or have been scarified or planted.

If a conservative estimate of 8 000 hectares are harvested each year, then according to the above analysis, 20% of the area or 1 600 hectares would have standing residuals with an average weight of 19 oven-dry tonnes per hectare or 30 400 tonnes. To this would be added the slash already on the ground on the 8 000 hectares (in the order of 43 oven-dry tonnes per hectare) for a total of 374 000 tonnes, say approximately 375 000 tonnes per year.

Translated another way, and given approximately the same mix of cuts as was sampled, there can be an anticipated quantity of 46 875 oven-dry tonnes of residue material per 1 000 hectares per year of cutover (including both the slash residue and the standing residuals).

The type of harvesting method would not greatly affect the quantities of this potential residue. The harvesting method would, however, determine the location of these residues and hence the cost of processing them into chips. For example, in a whole-tree operation most of the residues will be at roadside and little or none will remain on the cutover. On a tree-length operation the residues will generally be scattered randomly over the cut. In a short-wood operation the residues will sometimes be windrowed.

It follows that the type of harvesting system will also affect the availability of logging residues. If the material is piled at roadside as the result of a whole-tree operation, it is naturally more easily and cheaply gathered and chipped than if it is scattered randomly over a cut as the result of a tree-length operation.

Another difference between harvesting systems is the cleanliness of the residue material. Once on the ground, slash will not only accumulate dirt during the course of the harvest operation, but will have dirt added to it if gathering after harvest is attempted. It would be unreasonable to expect mechanical grapples to avoid collecting unwanted material while collecting slash for chipping. This unwanted material would greatly affect chipping efficiency especially with regard to the life of the chipper knives.

Slash would have the greatest chance of dirt accumulation in short-wood and tree-length operations. Whole-tree operations, where the trees are forwarded to roadside completely clear of the ground and then delimbed in a landing, have the least chance of contributing dirt to the residue material.

For these reasons and others, the whole-tree logging system is the most efficient system for gathering slash.

According to recent studies in Canada (Wiksten and Prins, 1980)[1], Sweden (Larsson, 1982)[2], and U.S.A. (Stuart et al, 1981)[3], a general conclusion reached concerning the recovery of logging residues is that branches and tops, to be recovered efficiently and economically, should be brought to a processing site while still attached to the tree. This implies that the retrieval of the forest biomass be done simultaneously with conventional logging operations and is most easily accomplished in the whole-tree logging system.

4.2 Regional Demand for Forest Residues

4.2.1 Introduction

This section explores the potential for the development of a market for wood fuel in the Miramichi region (Region 2) of the Province.

The subject is a very broad one, and some initial assumptions are necessary to provide a focus for the study.

A brief discussion of the nature of the fuel and the problems associated with its use will serve to suggest those fuel consumers which are most likely to become the beginnings of a fuel-chip market in the Region.

Green wood chips are a relatively low-grade fuel when compared with oil, coal, gas, or even processed wood products such as dried cordwood or pelletized fuel (reference Table 4.2.1 following). The high moisture content of the material makes combustion relatively difficult, and transportation, storage, and handling of wood chips is costly because the bulk and weight of the material are high relative to its heat content. However, the low cost of wood chips can justify the measures necessary to overcome these drawbacks in some situations. In every case the heating plant designed to fire wood chips will be much more expensive to build than the equivalent oil-fired plant.

The smallest conceivable heating plant would be a domestic furnace supplying heat to a single dwelling.

Residential-size units have been built which are capable of firing wet chips using automatic stokers. However, the problems of supplying fuel to such a unit, combined with the high capital

TABLE 4.2.1
COMPARISON OF FUEL HEATING CONTENT
AND VOLUME

	Heating Content			
	Btu's		kJ	
	Pound	ft^3	kg	m^3
Oil #2	19 075	1.02×10^6	44 356	36×10^6
Oil #6	18 274	1.1×10^6	42 493	40.9×10^6
Coal (Minto)	11 500	0.6×10^6	26 741	22.3×10^6
Wood Pellets (containing 12% MC)	7 480	0.26×10^6	17 393	9.7×10^6
Wood Residue:				
25% MC (11.2 #/ft^3)	6 800	0.08×10^6	15 810	2.8×10^6
40% MC (12.6 #/ft^3)	6 075	0.08×10^6	14 124	2.8×10^6
80% MC (16.1 #/ft^3)	4 725	0.08×10^6	10 985	2.8×10^6

cost would seem to preclude any large-scale use of such units in single-family dwellings in the near future. For example, wet chips occupy approximately twice the volume of the equivalent dry cordwood, so storage and handling would be a serious concern.

Work is currently underway on the development of a wood fuel product consisting of hardwood chips, dried to less than 10% moisture content and packaged in well sealed kraft paper bags in weights of 2 kg. This product is now being tested on the local (Fredericton) market and in the Eastern Seaboard area of the USA. It is intended to compete with fireplace logs as well as a supplement to wood burning or possible as the sole source of fuel in airtight wood-fired stoves.

Some work is being done locally on the development of an automatic stoker-feed for wood chips. This has met with some success and in fact wood suppliers have been approached to develop an acceptable fuel for such a unit. One supplier in another region of the Province is doing some work on the preparation of fuel, including the drying, gradation and packaging. The work has not yet developed to the point where a method of handling (packaging, if necessary), size of deliveries, method of delivery (receiving receptacle at residence) and cost are established.

In the commercial and institutional heating plant, the use of wood chips begins to look much more attractive depending upon the size of the load and the physical details of the site. It is often possible to improve the load factor (and hence cost effectiveness) of a wood unit by sizing it to supply base load while using an auxiliary oil unit to carry peak loads. This strategy allows a given investment in wood-fired equipment to

produce a greater reduction in annual oil consumption than would be possible if the same unit were installed at a smaller plant where it would be capable of supplying 100% of the load. This is due to the relatively short duration of peak space-heating loads. Typically, the annual average output of a space-heating plant will be in the range of 20% of the peak load. It is evident that, if this average output can be raised to 40% or 50% of the wood unit's capacity, the gross fuel savings will be more than doubled.

A wood-fired boiler can be used to maximum advantage in an industrial application where the load remains relatively constant for the entire year. In such applications, the average load may be as high as 75-85% of the maximum output of the unit, often resulting in a large gross saving on conventional fuel.

It seems apparent that the initial markets for wood fuel chips are most likely to be developed in the industrial and institutional sectors of the existing fuel market.

In order to assess the potential for wood fuel as a substitute for oil, it is first necessary to determine the oil consumption in Region 2 and develop from that an approximation of the portion which may be economically replaced by wood fuel.

4.2.2 Current Oil Consumption in Region 2

The largest consumers in the Region are: schools, hospitals, large commercial establishments, small industry (including fish plants, dairies and food processors), and large industries (including the pulp and paper mills and the mining operations).

The study examined the use of wood fuel in various applications currently utilizing fuel oil (#6 or #2) as their primary fuel. Establishments presently using electric power for space heating offer little or no opportunity for conversion to wood fuel since in many instances both the heat-generation and the heat-distribution systems would need to be replaced. Some electric heating systems utilize an electric hot-water heater (boiler) which could conceivably have potential for replacement by a wood-fired unit, but the opportunities would be very limited.

The following provides a brief summary of oil fuel consumed in the Region (refer to the Table 4.2.2 following for tabulated data).

Schools - There is a total of 73 schools using oil fuel (refer to Appendix 4.2.1). These schools are in the School Districts Nos. 6, 7, 8, 9, 10 and 39 and are all within the economical transport radius. The total oil consumption based on the year 1982/83 is 2 423 005 litres of #2 oil and 105 642 litres of #6 oil (532 997 Imperial gallons of #2 oil and 23 240 Imperial gallons of #6 oil).

It will be seen that many consume relatively little fuel and could best be served through use of a small, manually charged system using prepared residue or stick wood. Such a base-load unit is evaluated in the analysis which follows. The assumption is made that an attendant is available to stoke the furnace once or twice per day.

Certain of the larger schools (those designated with an asterisk), may, in some instances, depending on distance from source of wood fuel, be economical in the base-load mode provided there is an attendant at the school qualified to service the unit.

The study examined a typical above-average-size school with present oil consumption in excess of 100 000 litres (21 997 Imperial gallons).

Hospitals - Energy consumption in hospitals tends to be high relative to other institutions as a result of unusually high demand for hot water, heating and cooling, cooking of meals and, in certain of the establishments, a laundry. The list of hospitals in the region is contained in Appendix 4.2.1. The total oil consumed is 4 740 462 litres of #6 oil (1 042 776 Imperial gallons) for the year 1982/83.

The study examined a typical hospital with oil consumption in excess of 900 000 litres (197 976 Imperial gallons) per year.

Small Industry - The heat-energy consumption in small plants will vary considerably with the product and the extent of value added. Those involving food processing will generally be energy intensive. Examples of this include fish plants, dairies and beverage plants.

A review has been made of small industrial establishments in the region; there are more than 30 fish plants, one dairy and one beverage plant. A list of the fish plants appears in Appendix 4.2.1.

The load factor, that is, the relationship between peak load and total energy per unit of time, is very important in determining the potential for wood use. As noted earlier, it is desirable to maintain as high a load as possible at a high load-factor in order to utilize the capital assets to their maximum.

TABLE 4.2.2

SUMMARY OF OIL CONSUMPTION

Institutional & Industrial Sectors Region 2

(Note - for fuel consumption considerations, Region 2 is assumed to comprise a circular area having Newcastle as its centre and a radius of 70 km)

Sector	OIL CONSUMPTION			
	No. 2 Oil		No. 6 Oil	
	Litres	Imperial Gallons	Litres	Imperial Gallons
Schools, Small	1 432 004	532 997		
Large	991 001	217 994	105 642	23 240
Hospitals			4 740 462	1 042 776
*Small Industrial	2 491 208*	548 000*	8 782 872*	1 932 000*
Large Industrial			174 105 000	38 298 500
TOTALS	4 914 213	1 298 991	187 733 976	41 296 516

* Estimated total fuel consumption from partial sampling.

A fish plant, depending on product, may operate 20 hours per day over a 5-day week for upwards of six months during the summer. This becomes an interesting load in that it occurs in the warm weather period and therefore complements a purely heating load as would apply to a school or a large office complex. The study will examine a fish plant with a base-loaded wood-fired boiler of 100 HP.

The typical dairy or beverage plant represents a relatively small load, but one that remains reasonably constant throughout the year. The use of wood in such a plant would not differ appreciably from the fish plant, except that the boiler (wood energy-conversion system) would be smaller and utilized over 12 months of the year. As noted above there is but one dairy and one beverage plant in the region -- both relatively small. The total oil consumption that is identifiable to the study is 2 491 208 litres (548 000 Imperial gallons) of #2 oil and 8 782 872 litres (1 932 000 Imperial gallons) of #6 oil per year.

The information on oil consumption has been estimated from results obtained through energy audits of only 11 plants in the list as contained in Appendix 4.2.1. From these results an extrapolation has been made to develop total fuel consumed. While such an approach lacks great accuracy, it is indicative and on average may be quite representative.

Large Industry - Industrial process-heat loads offer the maximum potential return on an investment in conversion to wood-chip fuel. Because load magnitudes are relatively constant the year round, a large industrial load would represent a stable base market for a fledging chip-harvesting industry. The primary industrial fuel consumers in the region are involved in the forestry and mining industries.

The Mining Industry - Two large mines are located just north of Region 2 in an area which is near existing forest-harvesting operations. Both of these industries use considerable quantities of #6 fuel oil (Bunker C) to generate steam for use in ore-processing plants.

From enquiries it was learned that the larger of the two generated close to 900 million pounds of steam (approximately 9.22×10^{11} kJ) during 1982 and consumed 26.92×10^{6} litres of #6 fuel oil in their boilers.

In addition, approximately 8 750 000 litres (1 927 000 Imperial gallons) of #6 oil are consumed annually by the ore dryers which use the hot flue gas directly to predry ore.

It might be practical to install a wood-fired boiler operating in the base-load mode. For the plant referred to above, the size of boiler would be in the order of 50 000 to 60 000 pounds per hour (pph). It would operate at a very high load-factor assumed to be 80%.

The economics of such a wood-fired boiler will be addressed in Section 4.2.3 following.

The second mine in the region uses much less fuel, and records of steam production and fuel consumption are not as readily available. At the present time this mine is not in operation and its potential will not be factored into the wood potential calculations.

The Pulp and Paper Industry - There are three major mills in or near the region under study.

The Boise Cascade mill at Newcastle is a pulp mill which presently produces over 50% of its total steam requirements from hogged bark and other wood waste. During 1982, approximately 60 000 oven-dry tonnes of hog fuel were consumed. In 1983, the mill is expected to burn 72 000 oven-dry tonnes, of which 18 000 will be purchased residues from sawmills in the Region. It was estimated by a mill spokesman that, if fuel were available, up to 92% of their steam demand could be produced in their hog-fuel boiler. Using 1982 figures, then, Boise Cascade could potentially absorb approximately 38 000 oven-dry tonnes; or 76 000 tonnes of green fuel chips per year. In practice, some improvements in their fuel-handling system would be necessary to accommodate such an increase in wood-fuel consumption.

This firm is interested in purchasing wood fuel from outside sources and may be expected to make the necessary investment in fuel-handling facilities.

Acadia Forest Products Limited operates a groundwood pulpmill at Nelson. Part of their steam production is produced by burning hogged waste. Good records on steam prodution and fuel consumption were not available for the period before December, 1982. For the period November 28, 1982 to January 29, 1983, 27.56 x 10^6 pounds of steam were generated.

They estimate the 75% of this production was from wood residue.

At the present time, there is not much potential for this firm to increase wood-fuel consumption. However, they do have plans for expansion of their mill which would include a new boiler of a larger capacity. If this expansion proceeds, some potential may exist for expanded wood-fuel consumption.

The Consolidated Bathurst pulpmill at Bathurst, N.B. lies in the outer fringe of the region and represents a large potential market for wood-residue harvesting operations in Region 2.

This mill has a large steam plant which produced 2.069 x 10^3 GJ of steam from oil during 1982 (1.961 x 10^{12} Btu) (equal to an estimated 1 705 x 10^6 pounds of steam) resulting in a fuel consumption of 60.2 x 10^6 litres (13.2 x 10^6 Imperial gallons). They have plans to convert their black-liquor recovery-boiler to burn wood waste. However, they anticipate that they will be able to supply all of their demand for fuel from the mill process wastes.

The study will examine a wood-fired boiler of 50 000 pounds per hour (pph) operating in the base-load mode.

4.2.3 Potential for Use of Wood Residue in Region 2

For this analysis, as for the work in 4.2.2 above, it is assumed that the "region" consists of a circular area having Newcastle as its centre and a radius of 70 km.

The present oil consumption for the institutional and industrial sectors examined is summarized in Table 4.2.2.

The potential for conversion of a specific site to wood requires a detailed study of all aspects pertaining to the project. There are many factors which enter into a decision concerning use of wood as a fuel. Some of the more apparent ones are listed below:

- availability and price of wood delivered to the wood facility;

- return on investment for the capital cost of facilities as required for wood-energy conversion;

- availability of manpower and servicing capabilities at the plant; and

- projections for other fuel costs including oil, coal, natural gas and electricity.

In order to outline the scope of possibilities, a series of calculations has been done to indicate the total wood consumption for Region 2 given a rate of conversion of 10%.

It will be seen from Table 4.2.3 following that the potential for use of wood as a fuel in large industry far exceeds all other potential uses combined.

In reading the Table it should be understood that actual fuel consumed would be a mix of the three moisture contents. However, the total would not exceed in heat quantity that stated for any one moisture classification.

4.3 Forest-Residue Costs at Roadside

4.3.1 Harvesting Options

There are four basic methods of harvesting wood for the production of fuel chips, one of which is still in the embryonic stage. These methods can be broadly described as follows:

1. The retrieval of slash (branches and tree tops) and standing residuals as a separate operation following the harvesting of industrial wood. The residues are transported to a

TABLE 4.2.3

POTENTIAL WOOD CONSUMPTION IN REGION 2

BY LOAD TYPE

	Small Schools	Large Schools	Hospitals	Small Industry	Large Industry	TOTALS
Present #2 Oil Consumption						
Litres	1 432 004	991 001	--	2 491 208	--	4 914 213
Imp. Gal.	315 003	217 994		548 000		1 080 997
Present #6 Oil Consumption						
Litres	--	105 650	4 740 462	8 782 872	174 105 000	187 733 984
Imp. Gal.	--	23 240	1 042 776	1 932 000	38 298 504	41 296 520
Wood Consumption for 10% Conversion						
Tonnes @ 80% MC	576	447	2 221	--	81 597	89 960
Tonnes @ 40% MC	448	348	1 728	--	63 464	69 970
Tonnes @ 25% MC	400	310	1 542	--	56 664	62 470

central site for chipping and shipment. Various techniques and equipment may be used, but two main elements of cost are involved, namely, the cost of collecting and transporting the residues to a central point and the costs of chipping and loading the chips.

2. The chipping of branches, tops and even whole trees already brought to a central processing site by one or another of the procedures used in "whole-tree" harvesting. Here the costs of bringing the tops, branches and merchantable trees to the "landing" are part of the cost of producing the industrial wood. Only the costs of chipping and loading chips and the costs of harvesting what would otherwise be "standing residuals" are chargeable against the fuel chips.

3. The harvesting of low-grade stands -- usually of hardwoods or mixedwoods -- exclusively for fuel. Such stands may be harvested by any method, but the whole-tree system is undoubtedly the most economical. Clearly all costs are chargeable against the only product produced, namely, fuel chips. However, because the percentage of stemwood is much higher than when only residues are processed, costs per unit of output of chips are lower than for chips produced in "clean-up" operations.

4. The latest developments -- those still in the embryonic stage -- involve special machines which roam over a harvested area picking up the residue and simultaneously processing it in some way. The processed residue is then taken to a central location for shipment to the user.

Since 1976, quite a number of trials of chipping forest residues have been conducted in the Atlantic Provinces and elsewhere. In most cases, accurate records of costs were kept and often reliable time studies were made. These records provide the means for estimating costs not only for the trials as conducted, but also by extrapolation for variations in the procedures used.

4.3.2 Comparative Costs

A major obstacle in bringing the results of all these field trials to a common base arises from the fact that they all took place during a period of high inflation. In order to compare the results of these field experiments, all recorded costs have been adjusted to a "May 1983" basis by assuming inflation of costs to have equaled the rise in the Consumer Price Index during the period in which these studies occurred. The inflation factors used are as follows:

Factors Used to Adjust for Inflation of Costs

Year and Month	C.P.I.	Multiplier to bring Costs to May 1983 base
1976 (June)	148.7	1.85
1977 (June)	160.2	1.72
1978 (June)	175.1	1.57
1979 (June)	190.6	1.44
1980 (June)	209.9	1.31
1981 (June)	236.8*	1.16
1982 (June)	263.3*	1.05
1983 (May)	275.2*	1.00

*In 1981, Statistics Canada adopted a new C.P.I. base of 100.0, but for purposes of this study the values for 1981, 1982, and 1983 have been converted to the base previously in use.

Anyone wishing to substitute different factors to adjust for the effects of inflation can do so by first recalculating the original cost figures by applying the above conversion factors in the reverse way to that in which they have been used, that is, by dividing by them rather than using them as multipliers.

To further bring our cost and production data to a uniform basis, all results are given in metric tonnes at moisture contents of 25, 40 and 80 percent on an oven-dry weight basis. Furthermore, 15 percent has arbitrarily been added to the costs of "company" operations so as to make them more compatible with the "costs" of contracted projects which are presumed to have included a profit element of about that amount. In no case was any Crown timber royalty included in the costs of fuel chips.

4.3.3 Factors Affecting Unit Costs

A few facts about unit costs are almost self-evident, but should be pointed out at the start. First, the costs of collecting forest residues and transporting them to a central point for processing increase in inverse proportion to the oven-dry weight of material retrieved per unit of area. Associated with this fact is that the higher the proportion of large or medium-size standing residual trees in the mixture, the lower the unit costs of retrieval; this point also applies to the costs of chipping. In fact, chipping costs are greatly affected by the size of the individual pieces of wood fed into the chipper. However, almost as important a factor in increasing chipping costs is time lost in waiting for material to process. It is axiomatic that the lowest chipping costs for any given mixture of feedstock will be achieved when there is no time lost in waiting for material.

The costs of chipping are affected by the amounts of grit and gravel caught up in the residues. The more such contaminants there are, the more often chipper knives must be changed, sharpened and replaced. This adds to costs of labour, material and down-time. Clearly whole-trees which are carried to the landings on forwarders contain the least contaminants. Slash which is picked up off the cutover and skidded to landings contains the most abrasive material. Whole trees which are skidded to landings are likely to have an intermediate abrasive content. These facts contribute to make chips from whole trees the cheapest and those from clean-up operations the most expensive.

Throughout these calculations of costs it has been assumed that the moisture content of wood at any level likely to be encountered in the field (i.e., above fibre-saturation point) will not affect the costs of chipping a given volume of wood of a given species and form. Of course, moisture content has a major effect on the value of a given weight of wood intended for fuel.

In the following discussion the costs of fuel chips loaded in vans ready for transportation to the user are given in Canadian dollars of May 1983, per tonne of wood at 80 percent moisture content (oven-dry basis) followed in brackets by the equivalent costs at 25 and 40 percent moisture content in that order.

4.3.4 Clean-up Operations

This is the most expensive way to produce fuel chips, if done with conventional equipment. Machines are being evolved which aim at lowering these costs, but so far there is little reliable information on their performance.

Our analyses of costs are based on tests made in New Brunswick in 1976([4],[5]) and 1979([6]). They range from a low of $14.07 per tonne ($20.26 and $18.09) to a high of $43.86 per tonne ($63.16 and $56.39) with an average for eight different experiments of $31.85 per tonne ($45.87 and $40.95). The lowest cost figure is associated with a retrieval of 104 oven-dry tonnes per hectare; the highest cost relates to a retrieval rate of 33.7 oven-dry tonnes per hectare. The average cost probably relates to retrievals in the range of 70 to 80 oven-dry tonnes per hectare.

4.3.5 Whole-tree Harvesting

The figures dealing with this method of producing fuel chips are based on eight experiments in Newfoundland([7]), Prince Edward Island* and New Brunswick([4],[5],[6]). The average cost per tonne at 80 percent moisture content in this group was $11.97 ($17.27 and $15.39). The range is from a low of $6.75 ($9.72 and $8.68) to a high of $31.45 ($45.29 and $40.44). However, the group breaks down into two subgroups; the one being characterized by a high proportion of stemwood and little lost time and the other by relatively small quantities of residual trees and much lost time. The first subgroup has an average cost of $7.37 ($10.62 and $9.48) while the average for the other subgroup is $18.08 ($26.03 and $23.24). It seems reasonable to expect that the chipping of slash from whole-tree and small whole-tree residuals can be achieved in 1983 for $7.75 (± 15%) per tonne at 80 percent moisture content, provided that no charge for logging or royalty is made.

4.3.6 Whole-tree Harvesting for Fuel Chips Only

Three experiments -- one each in Newfoundland, Prince Edward Island and New Brunswick -- allow estimates to be made of the costs of producing fuel chips from low-grade stands of hardwood and mixedwood. In these cases, total costs of logging and chipping must be charged against the only product, namely, chips. The costs (May 1983) of producing chips in these three experiments were as follows:

Dollars per Tonne			Tonnes (oven-dry) of Chips per Hectare	Average Specific Gravity (oven-dry) of Mixture
At 80% MC	At 25% MC	At 40% MC		
$18.24	$26.27	$23.45	129.0	0.461
$22.14	$31.89	$28.47	87.5	0.469
$24.37	$35.10	$31.34	65.2	0.447

*The report of the Prince Edward Island project has not been published.

These figures are remarkably consistent when one takes account of the quantity of chips produced per hectare harvested and the average dry weight of the mixtures of species.

From the foregoing cost data it is evident that the cheapest method of producing fuel chips from forest residues is when they are made at a landing where the whole trees are processed for the production of industrial wood, provided that no harvesting costs are applied to the chips produced from slash. The second lowest cost results from whole-tree harvesting of low-quality stands exclusively for fuel chips. The most expensive chips are those produced in a separate slash-retrieval operation following conventional short-wood or tree-length harvesting of industrial wood. There was no clear evidence of any difference in costs of clean-up operations following these two types of harvesting systems.

4.3.7 Specialized Slash-processing Machines

We have no reliable information on the costs of producing wood fuel with the new generation of machines designed specifically for the purpose of gathering and processing forest residuals for this end-use. Nova Scotia Forest Industries Ltd. are experimenting with a Bruks chip harvester model 1000 CT which is a machine that travels over a harvested area picking up logging debris and chipping it as it goes. The Company has not developed firm figures on its costs yet, but are of the opinion that costs run at about $22 to $23 per green tonne of chips loaded in vans, equivalent to about $26 per green tonne after adding 15 percent profit. The moisture content of the year-old, budworm-killed slash processed is probably about 40 percent (oven-dry basis).

The "RECUFOR", another slash-processing machine, developed by the Forest Engineering Research Institute of Canada (FERIC) has undergone some tests, but is presently being redesigned to function as a stationary machine to work in tandem with whole-tree harvesting systems. We can therefore not report or even suggest what production costs it may develop.

All the costs given above are unsubsidized. However, all the processes described result in the areas treated requiring very little, if any, site preparation prior to artificial planting. The total economy of producing fuel chips can therefore be subsidized to the extent of up to about $125 per hectare, if need be, and still leave it a desirable option where plantations are to be established. The subsidies could be in the range of one to four dollars per oven-dry tonne depending upon the rate of residual retrieval per hectare.

4.4 Competitive Value of Wood Fuel at Roadside

4.4.1 Introduction

This section of the study will develop the value of wood fuel delivered to a heat-producing facility. It should be noted that the "value" of wood fuel at roadside differs from the "cost" of wood-fuel at roadside. The "value" derived will be that computed to be necessary in order to compete with the present fuel, that is, #2 or #6 oil, and will contain all costs in excess of those associated with the existing system, including financing of capital for the assets.

A transportation component has been developed and the economic cost at roadside (at the forest-residue generating area) is summarized in Table 4.4.1 following.

The values have been developed based on the following assumptions:

1. Values will be developed for the wood residue at roadside which, with delivery costs added, will be competitive with oil at the heating plant/s.

2. Bunker C (#6 oil) has a heating content of 41 830 kJ/litre (180 000 Btu's/Imperial gallon), its efficiency of conversion is 80% in large boilers and 75% in small boilers (300 hp and below).

3. No.2 oil has a heating content of 38 340 kJ/litre (165 000 Btu's/Imperial gallon), its efficiency of conversion is 75%. This reflects the fact that it is normally used in small boilers.

4. The wood residue, oven-dry, has a heating content of 19 765 kJ/kg (8 500 Btu's/per pound), the efficiency of conversion is 65% as delivered. This assumes a moisture content of 80% (dry basis) and it is recognized that the efficiency may rise marginally for drier fuel; however, the value given (65%) represents a realistic average.

5. The moisture content (MC) of the wood as determined from a series of tests on the wood residue examined was found to range from 25% to 80% (dry-weight basis). The table below summarizes MC and the heat content for each.

Residue Age	Moisture Content Dry Basis	Moisture Content Wet Basis	Heat Content Btu/#	Heat Content kJ/kg
3-5 Yrs	25%	20.0%	6 800	15 810
1-3 Yrs	40%	28.5%	6 075	14 124
Green Chips	80%	44.5%	4 725	10 985
	Oven-Dry		8 500	19 765

This evaluation will examine the following as potential consumers of wood residue fuel;

1 - a small school
2 - a large school
3 - a hospital complex
4 - a fish-processing plant
5 - a mining/processing operation requiring a wood-fired boiler
6 - a large industrial load having a wood-fired boiler in place.

TABLE 4.4.1 - WOOD FUEL VALUE AT CONSUMING PLANT AND ROADSIDE - PART 1

		WOOD FUEL CONSUMED TONNES			OIL DISPLACED		
	CAPITAL EXPENDITURE($)	80% MC	40% MC	25% MC	LITRES	IMPERIAL GALLONS	VALUE($)
1. Small School	50 000	203	160	143	51 000	11 230	15 147
2. Large School	203 000	403	313	280	100 000	21 997	29 700
3. Hospital	563 500	3 193	2 483	2 219	726 751	159 866	160 750
4. Small Industrial	565 000	1 071	837	747	248 860	54 800	54 800
5. Large Industrial (with new wood-fired boiler)	4 245 000	51 713	40 220	35 930	11 034 000	2 430 000	2 427 480
6. Large Industrial (wood-fired boiler existing)	Boiler existing (no capital required)	29 831	23 201	20 726	6 365 049	1 400 000	1 400 000

The residential sector does not presently make use of chips as a fuel except in a few isolated test installations. If work currently underway is successful in developing a clean, safe unit with full automatic features to monitor for safety and fuel feed, so as to develop confidence on the part of users **AND** supposing that a clean (low in dust and free of insects), low moisture content and easily handled fuel at a competitive price is available, **THEN** residential use of wood-chip fuel would, in all probability, rise substantially.

It should be noted that the analyses which follow assume that an oil-fired boiler is already in place. It is further assumed that in all scenarios, except #6, the wood-fired boiler must be added to the plant and in these cases the wood-fired option must show sufficient monetary gain to recover its financing costs over a reasonable period of time and still operate at a lower cost than the equivalent oil-fired unit in terms of fuel cost, maintenance, etc. If the new wood-fired unit was to be compared with a new oil-fired unit of equivalent size and on a comparable operating routine, the economic status of the wood-fired unit would be substantially improved. Likewise, considering, as for #6 above, a plant in which the wood-fired boiler is already in place, the economics are much improved.

4.4.2 A Small School

An study was done of the potential for savings at a small school having a hot-water heating system presently fired with #2 oil, with an attendant at the school throughout the normal day period of 8 am to 5 pm.

Assumptions:

a) the total heat-energy consumption for the average year is 1.96×10^9 kJ (1.85×10^9 Btu's). This equates with 68 000 litres (15 000 Imperial gallons) of #2 oil having a cost of 29.7¢/litre ($1.35/Imperial gallon).

b) the wood-fired boiler is sized to displace 75% of the #2 oil. This is approximately:
203 tonnes (224 tons) of wood at 60% MC (dry basis)
160 tonnes (176 tons) of wood at 40% MC (dry basis)
143 tonnes (158 tons) of wood at 25% MC (dry basis).

c) the capital cost for the wood-fired boiler is estimated to be $50 000.00 installed. This includes a stoker-type feeder for wood chips and a chip-storage hopper. (See Appendix 4.2.2).

d) there will be an allowance of $2 000/year for additional servicing costs associated with the wood-fired boiler.

e) the wood cost must not exceed $40.13/tonne ($36.41/ton) (at 80% moisture content) as delivered to the school. The development of this cost is contained in Appendix 4.2.3.

f) the payback period is assumed to be 10 years. The savings over a period of one year are estimated to be $5 000.00 with a capital expenditure of $50 000.00.

4.4.3 A Large School

A large school is defined here as one consuming 150 000 litres (33 000 Imperial gallons) or more per year. There are a total of eight schools in the region which qualify; these are marked with an asterisk in list of schools as contained in Appendix 4.2.1.

The analysis below assumes:

a) an annual oil consumption per year of 150 000 litres (32 996 Imperial gallons). The potential savings in fuel are in the order of 100 000 litres/year (21 997 Imperial gallons per year).

b) there is an attendant at the school who can check the wood-fired unit two or three times per day.

c) the capital cost for the wood-fired equipment based on an outdoor wood-fuel receiving hopper with the boiler installed in the existing building is $203 000. See Appendix 4.2.2.

d) there will be an allowance of $5 000 per year for additional servicing costs associated with the wood-fired boiler.

e) the wood cost must not exceed $11.17/tonne ($10.13/ton) (80% MC wood) as delivered to the school. The development of this cost is contained in Appendix 4.2.3.

f) the payback period is assumed to be 10 years. The savings over a period of one year are required to be $20 300 with a capital expenditure of $203 000.

4.4.4 A Hospital Complex

The hospitals of the district within the economic transportation range of 70 km are listed in Appendix 4.2.1.

The analysis below assumes:

a) an annual oil (Bunker C) consumption of 900 000 litres (197 976 Imperial gallons). The potential saving in oil per

year is approximately 726 751 litres (159 866 Imperial gallons) with the boiler operating in the base-load mode.

b) the present staff assumed to be four to five operators would be adequate to receive the wood and efficiently operate the boiler. The wood-handling system is fully mechanized.

c) the capital cost based on a new wood-fired boiler, wood handling and storage and auxiliaries installed is estimated to be $563 500.00. This system would be eligible for a grant, (estimated at 15%) resulting in a net cost of $ 478 975.00. (See Appendix 4.2.2).

d) there will be an allowance of $15 000.00 per year for additional servicing costs associated with the wood-fired boiler.

e) the wood cost must not exceed $25.06/tonne ($22.74/ton) (80% MC wood) as delivered to the hospital. The development of this cost is contained in Appendix 4.2.3.

f) the payback period is assumed to be eight years.

The savings over a period of one year are estimated to be $59 871 with a capital expenditure of $563 500.

4.4.5 Small Industrial Plant

Consider a fish plant as the typical small load.

A fish plant with processing and freezing facilities usually operates at a high load factor for a period of six to eight months per year. The operating period in New Brunswick runs from April/May through to September/October, predominantly warm months. Should a load be available, such as a school, its basic heating load, during cold months, would complement that of the

plant. A combination of two such loads would only result in a gain to the owner of the wood-fired boiler if the winter load was essentially the same as the summer process load since the owner is committed to the relatively high cost of having to retain operating staff during the winter when fish plants are normally shut down.

This analysis assumes the following:

a) The process load has a peak requirement of 300 hp (10 000 pph) and an energy requirement over six months of 18.4 x 10^9 kJ (17.4 x 10^9 Btu's).

b) A 100 hp wood-fired boiler would be installed and is assumed to operate at 85% load factor over the six months period - the unit will generate 7.8 x 10^9 kJ (7.4 x 10^9 Btu's) during the period.

   It will consume 1 071 tonnes (1 200 tons) of wood fuel (80% MC) and will displace an estimated 248 625 litres (54 691 Imperial gallons) of Bunker C oil.

c) The efficiency of conversion for the wood fuel is estimated to be 65%.

d) The existing oil-fired boiler uses Bunker C oil at 41 830 kJ/litre (180 000 Btu's/Imperial gallon), its efficiency of conversion is 75%.

e) The operating staff would be increased by one man only for wood handling. Estimated cost is $15 000 per year. (Per year of six to eight months).

f) Maintenance and servicing costs would rise by $12 000 per year.

g) Insurance costs on the new assets would be 1½% of applicable capital costs or $7 200.00

h) The estimated capital cost for the 100 hp boiler and its auxiliaries installed is $563 500.00 (see Appendix 4.2.2).

The costs are identical to those developed for the "Institutional" unit (hospital). It is assumed that a grant of 15% would be available leaving a net cost of $478 975.00.

i) Allow for payback over four years.

j) It will be seen from the costs as developed in Appendix 4.2.3 that this option is not competitive at zero cost for wood. As noted above there may be an improvement in return on investment if a predominantly space-heating load, such as one or more institutions, were available.

4.4.6 Large Industrial Plant (with addition of a new wood-fired boiler)

The large heating and process loads in the region are associated with industry, either pulp and paper or mining. This analysis assumes a mining operation having a peak load of 200 000 to 400 000 pph operating at a high load factor throughout the year. It would be reasonable to consider a wood-fired boiler rated 50 000 pph operating at a high load factor of 80%. Although not included in the analysis, it might be economically feasible to install a back-pressure turbine-generator to generate electric power.

This analysis assumes the following:

a) The process load has a peak requirement of 300 000 pph and an annual energy requirement of 2.2×10^{12} kJ (2.1×10^{12} Btu's).

b) The present fuel is Bunker C - the boiler has a conversion efficiency of 80%.

c) A 50 000 pph wood-fired boiler would be installed and is assumed to operate at 80% load factor throughout the year. It will generate 0.37×10^{12} kJ (0.35×10^{12} Btu's) and will consume:

51 713 tonnes (57 039 tons) of wood @ 80% MC
40 220 tonnes (44 363 tons) of wood @ 40% MC
35 930 tonnes (39 631 tons) of wood @ 25% MC
and will displace an estimated 11 034 000 litres (2 430 000 Imperial gallons) of Bunker C.

d) Capital cost for a boiler rated 50 000 pph complete with air heater, dust collectors, fans, control, wood storage and handling, foundations and buildings estimated to be $4 245 000 installed. Assuming a grant of 15%, the net cost would be $3 608 000. (See Appendix 4.2.2).

e) Operating staff would be increased by six men at $30 000 each = $180 000 per year.

f) Maintenance and servicing costs increased by $140 000 per year.

g) Insurance costs on new assets at 1.5% of assets - (1.5% of $4 000 000) = $60 000.

h) The wood cost delivered to the plant in order to be competitive with oil is as noted below. The development of these costs is contained in Appendix 4.2.3.

$16.57/tonne ($15.03/ton) @ 80% MC
$21.30/tonne ($19.33/ton) @ 40% MC
$23.85/tonne ($21.64/ton) @ 25% MC

The savings over a period of one year are required to be $1 190 640 with a capital expenditure of $4 250 000.

4.4.7 Large Industrial Plant (having an existing wood-fired boiler and auxiliaries)

The capital cost for the wood-burning facilities greatly influence the "value" of fuel at the consuming plant. The following analysis assumes that a wood-fired boiler and all auxiliaries including wood storage and handling are in place and no capital expenditure is required.

It is, however, reasonable to assume that some additional costs would apply for handling, servicing and maintenance, that is, variable costs which relate to level of production. Costs such as insurance and administration would already form part of the firm's annual operating costs and need not be factored into the analysis. There must, however, be some incentive for the firm to move into additional wood. To provide this incentive it is assumed that 25% of the gross savings from oil reduction remain as a net saving to the fuel consumer after all costs are accounted for.

Such a scenario can only be based on the assumption that the establishment had earlier decided to burn wood fuel and they now must procure wood fuel to supplement their earlier needs or alternatively to replace a portion which may no longer be available to them.

This analysis assumes the following:

- the establishment has need for 30 000 tonnes (33 075 tons) of wood chip fuel at 80% MC per year.

- this wood fuel is to displace #6 oil having a conversion efficiency of 80%. The cost of the oil is 22¢ per litre ($1.00 per Imperial gallon).

- the conversion efficiency for the wood at 80% MC (dry basis) is 65%.

- no additional charges are made against the wood fuel for capital costs since the assets are deemed to be in place. Charges will be made against the wood fuel for wood handling and for maintenance and servicing as follows:

  - the operating staff would be increased by four men at $30 000 each = $120 000/year.

  - the maintenance and servicing costs for the wood-handling portion only would increase by $40 000 per year.

  - the wood cost delivered to the plant in order to be competitive with oil is as noted below. The development of these costs is contained in Appendix 4.2.3.

  $29.84/tonne ($27.07/ton) of 80% MC wood
  $38.37/tonne ($34.81/ton) of 40% MC wood
  $42.95/tonne ($38.97/ton) of 25% MC wood

The net saving (or profit) is $350 077 per year.

4.4.8 Transport Costs

The cost of transporting wood chips from roadside to consumer is comprised of a number of components, including the over-the-road vehicle costs which this subsection of the report describes. Since the movement of the wood chips would take place over a combination of gravel and asphalt road surfaces, and the weight limits on the provincial highway system in the area restricts maximum loads, a 5-axle tractor-trailer combination was selected as the typical vehicle. It is also assumed the typical wood-chip van (trailer) would have a length of 12.2 m, a width of 2.44 m and a height of 2.44 m. Discussions with a wood-chip-van dealer indicated such a van would have a total carrying capacity by volume of 86.6 m^3. This volume is made possible because of the recessed bottom of this type of van.

The typical 5-axle tractor-trailer combination has a gross vehicle mass of 39 685 kg and a tare weight of 15 675 kg. This results in a maximum permissible payload of 23 800 kg. The above vehicle characteristics conform to the maximum allowable loads in New Brunswick.

The cost of operating a 5-axle tractor-trailer combination was estimated utilizing a number of sources. It should be noted the costs discussed in this section are in terms of 1983 dollars. The 1983 cost per vehicle km is $1.16 assuming a 260-day operating year and total travel by the tractor-trailer of 128 000 km. The cost components comprising the $1.16 per km estimate include driver's wages, fuel, maintenance, parts, tires and tubes, lubricants, insurance and registration. The capital cost for the equipment, interest and overhead produces an additional 29 cents per km.

If it is assumed a 15 percent profit is a reasonable return on investment, then the total vehicle operating cost is $1.67 per vehicle km. With a maximum payload of 23.8 tonnes hauled, the cost per tonne-km is 7.02¢. Thus the 7.02¢ per tonne-km was utilized to calculate the vehicle costs of transporting wood chips for an average return haul of 140 km. The cost per tonne-km was adjusted accordingly to reflect the situation where the wood-chip payload bulked out by volume rather than weighing out.

The cost of transporting wood chips to various consumers is summarized in Table 4.4.1.

4.4.9 Consideration of Other Fuels

This section of the report examines the use of other fuels including coal, electric power, propane, #2 and #6 oil, and natural gas. A summary Table 4.4.2 has been developed as a means of comparing each fuel as to cost, availability, capital for combustion, storage and handling equipment, cleanliness, personnel requirements and reliability of supply.

Coal - The Region under study is within an economic transport distance of the Minto coal fields of central New Brunswick. The coal from this deposit is relatively high in ash and sulphur. Further, it is understood that much of it is committed to the New Brunswick Electric Power Commission for use in two electric-power generating stations.

The estimated cost per tonne for coal delivered to Newcastle would be $70.00. The heat content is 26 750 kJ/kg (11,500 Btu's/pound), the ash content runs as high as 18 to 20%. The efficiency of conversion can be as high as 80% in large boilers and around 75% in smaller boilers.

The facilities for storage, handling and combustion of the fuel are similar to those employed in wood-fired plants and have a capital cost of some two to three times those of comparable facilities using oil fuel.

Electric Power - This form of energy is undoubtedly the cleanest, the most efficient and offers a low capital cost. The cost for the electric power is higher on a per unit basis (see Table 4.4.2 following).

Electric energy may be used in a distributed system with heating elements spread throughout the facility or it may be used in a central boiler.

Propane - This is also a very clean fuel and can be easily burned with good efficiency. It is often used in cooking stoves and in applications within industry where a clean exhaust stream is a requirement.

It is used extensively as a fuel for internal combustion engines driving transport and handling equipment within a confined space. It would not prove attractive for larger boilers in New Brunswick due to its cost relative to heavy oil.

#2 Oil - This grade of oil is commonly used in household heating-systems and small industrial and institutional boilers having capacities of up to approximately 150 hp. Its combustion is reasonably clean. The efficiency of conversion varies with the design and condition of the system from 65 to 80%.

The capital cost for these small systems is lower than for the other systems under consideration.

If it is assumed a 15 percent profit is a reasonable return on investment, then the total vehicle operating cost is $1.67 per vehicle km. With a maximum payload of 23.8 tonnes hauled, the cost per tonne-km is 7.02¢. Thus the 7.02¢ per tonne-km was utilized to calculate the vehicle costs of transporting wood chips for an average return haul of 140 km. The cost per tonne-km was adjusted accordingly to reflect the situation where the wood-chip payload bulked out by volume rather than weighing out.

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The capital cost for these small systems is lower than for the other systems under consideration.

TABLE 4.4.2 - COMPARISON OF ENERGY SUPPLY COSTS FOR VARIOUS FUELS
(Part 1)

Fuel	Capital Cost (Relative)	Efficiency of Conversion (Typical)	Heat Content of Fuel	Unit Cost $	Cost Per 10^6 Btu $
Coal	2.5	80%	26 750 kJ/kg (11,500 Btu's/ pound)	$70/t	3.45
Electric Power	1.8	90%	3 600 kJ/kWh (3,413 Btu's/ kWh	0.05/kWh	16.27
Propane	1	85%	26 161 kJ/L (112,724 Btu/ Imp gal)	0.32/L	14.39
#2 Oil	1	75%	38 340 kJ/L (165,000 Btu's/ Imp gal)	1.35/ Imp gal	10.90
#6 Oil	1.3	80%	41 830 kJ/L (180,000 Btu's/ Imp gal)	1.00/ Imp gal	6.94
Natural Gas	1	85%	37 258 kJ/m^3 (1,000 Btu's/ ft^3)	4.70/ 10^3 ft^3	5.53
Wood Chips (@ 80% MC)	3	65%	10 985 kJ/kg (4,715 Btu's/#)	20/t	2.96

TABLE 4.4.2 - COMPARISON OF ENERGY SUPPLY COSTS FOR VARIOUS FUELS (Part 2)

Fuel	Avail-ability (1)	Storage & Handling Requirements	Cleanliness	Personnel Requirements	Reliability of Supply
Coal	medium	large area	poor	high	good
Electric Power	excellent	none	excellent	nil	excellent
Propane	medium	moderate	excellent	nil	good
#2 Oil	medium	moderate	medium	nil	good
#6 Oil	medium	moderate	poor	minimal	good
Natural Gas	N/A	moderate	excellent	nil	N/A
Wood Chips	medium	large area	medium	high	good

(1) - This item relates to "Access to Supply".

#6 Oil - This grade of oil is used extensively in large boilers and process burners as required for drying and processing of ore. It burns efficiently, in the order of 80% and above, in large boilers. It must be heated and admitted into the burner under pressure sufficient to atomize the fuel for improved combustion. It does create an environmental problem if the fuel is high in sulphur.

It will be seen from Table 4.4.2 that its per-unit cost for heat energy is reasonably low.

Natural Gas - A firm decision to install a natural-gas pipeline through the Province has not yet been concluded. It has been stated that, should a pipeline be installed, the selling price for the gas to distributors would be at 60% the price of oil. After allowing for the distribution and servicing component the cost may well approach the cost of oil. The analysis in Table 4.4.2 assumes that gas would have a price equal to 85% that of oil.

The natural gas would be a very clean fuel and facilities required for conversion could be low in cost. It burns very efficiently and in some parts of the country is used in all sizes of boilers within reach of the pipeline. It is expected that this fuel will not have any impact on use of wood for the foreseeable future since planning and construction for the main and distribution systems require some five years after the decision is made to proceed.

4.5 Monitoring of Wocd Deliveries

Since there are a number of important variables which affect its quality as a fuel, some means must be developed to serve as a "measurement" of the variables such that payment reflects in a meaningful way the heat-producing capacity of the fuel.

The factors that must be considered in evaluating wood fuel are: composition of fuel mix such as bark, sawdust, chips, shavings; presence of contaminants such as mud, stones or metal; level of moisture, including the presence of snow or ice: ash content and particle size. Other factors which must be considered include, method of transport, means of off-loading, and handling facilities at the receiving plant.

Some suggested guidelines which may be useful in the sale or procurement of wood fuel follow:

- the wood-fuel mix be sized by means of hogging and/or screening such that maximum size does not exceed 40 mm x 40 x 40 (1½" x 1½" x 1½");

- vehicles should be weighed "in" and "out" and a "tare" weight provided in some printed form from approved scales;

- delivery shall be made in a covered self-unloading vehicle such as a live-bottom semi-trailer;

- purchaser will provide a receiving bin/hopper with capacity to permit unloading a van in 20 minutes;

- supplier is to maintain an inventory of wood-fuel of not less than two weeks' consumption by the purchasers;

- the maximum concentration of noncombustible residue (ash plus dirt) shall not exceed 3% by weight of the oven-dry fuel;

- the moisture content would very much influence the price paid for the fuel - the base price would be paid for fuel within a moisture range of 80% to 120%. For moisture contents above 120% to 150% the price paid would be reduced on a proportional basis, with no payment made for fuel in excess of 150% MC. For wood fuel below 80% MC the base price would be increased. The penalty and bonus would relate to the base price;

- the purchaser would arrange for determination of moisture, although the supplier might conduct separate tests from the same samples.

Section 4 -- References

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SECTION 5

ENVIRONMENTAL CONSIDERATIONS

5. ENVIRONMENTAL CONSIDERATIONS

5.1 Environmental Effects of the Removal of Slash and Standing Residual Trees from Logging Sites

There is no practical means of economically removing logging debris from partial or "selective" forest harvesting. Such salvage is practicable only in the case of genuine clear cuts and what are commonly called "commercial clear-cuts". The latter are logging operations in which all timber for which there is a profitable market is taken and the rest is left -- either standing or knocked down.

This report is not concerned with the good or the bad environmental consequences of clear cutting, but only with the incremental effects of removing the slash and residual trees in addition to the marketable, industrial fibre.

Now that plantations are becoming a major element in intensive forest management, some way of removing or windrowing slash must be accomplished between harvesting one crop and planting the next. The removal of logging debris and residual trees therefore combines a potential energy-conservation measure with a useful forest management function where planting is to be done. This is a very important positive influence which compensates for several negative ones of lesser significance.

The environmental impact of slash removal uppermost in many investigators' minds is the loss of soil nutrients from the site. It is now fairly generally agreed that, on most sites, the loss of nutrients thus incurred is negligible when spread over "normal" rotations of many decades. The exceptions are those sites where the soils are very shallow or very wet[1].

owever, in the case of so-called "fuel plantations", where otations may be in the five- to ten-year range, soil-nutrient epletion is significant enough to require artificial fertiliza-ion to compensate for the losses of natural nutrients. The oss of trace elements from the forest environment is suspected f being a limiting factor in some instances, if more than wood nd bark is removed in harvest[2]. It can be said with ertainty that it would be preferable to leave foliage and small vigs on the site, if practicable means could be found to do hat because it is these parts of trees which contain the ighest concentration of nutrients and minerals[3,4].

s logging slash dries it becomes highly inflammable. Its emoval from the site clearly reduces the likelihood of forest ires getting started. To avoid, or at least minimize, the anger of wildfire, slash is sometimes deliberately burned under ontrolled conditions. While this treatment has some minor dvantages over slash removal (e.g., some, but by no means all, f the nutrients remain on the site) on balance the physical emoval of slash is the better choice. Apart from the risk of ontrolled fire becoming uncontrolled, hot slash fires do severe amage to the surface layers of soil[2,5].

ntil a site is revegetated -- probably a year or so after the arvest, the removal of slash by any means expose the soil to un, wind and rain. Under these conditions there is a tendency or the soil to bake; in turn, this reduces its capacity to bsorb precipitation. This situation coupled with the fact that here is no cover to break the impact of raindrops, is conducive o erosion, especially on slopes or in tracks cut by the passage f heavy machines. These adverse factors are considerably worse ollowing the burning of slash than after its physical emoval[5,6].

The effects of any method of slash removal on wildlife are mixed. The mobility of larger animals is improved, but small creatures are at least temporarily deprived of protective cover. The nature of the food supply is changed little, if at all.

Besides reducing the danger of fire, slash removal also lessens the opportunities for fungi and insect attacks to spread to nearby standing timber. However, apart from the nutrients slash furnishes, it also contributes fibrous texture to the soil which may endure for decades and improve the soil's moisture absorbency. This is particularly true of coniferous species[2,5].

The slash of some species contains a source of seed which may persist for several years. In New Brunswick this applies to jack pine. In fact, logging slash, if not excessive, generally tends to favour the natural generation of the forest, even though the removal of slash is a prerequisite for the establishment of plantations.

When one takes into account the reduction in the risks of fire, insects and diseases, the improvement in aesthetics and the preparation of sites for planting, the removal of logging debris for the production of energy should, on balance, be welcomed in most cases. However, on critical sites -- notably where soils are very wet or very thin or on steep slopes -- complete removal of woody matter can impoverish the site through unacceptable nutrient loss or soil erosion.

5.2 Environmental Effects of Nonresidential Use of Wood as Fuel

The nature of logging residues is such that they are conveniently burned only in combustors designed specifically for that kind of fuel and having a relatively high efficiency rating.

That being the case, the chief environmental advantage is that wood contains next to no sulphur and hence wood smoke is almost free of sulphur dioxide -- a major contributor to the formation of acid rain. Well controlled combustion of wood also releases lower levels of another component of acid rain, namely, oxides of nitrogen, than does the burning of fossil fuels. On the negative side, wood smoke is high in particulates[7]. Therefore, large wood combustors should be equipped with some form of dust-collecting facility.

Wet wood held in storage will sustain the growth of molds and fungi. Some people are allergic to the spores and hyphae of such growths[8]. For that reason, wet wood in any form but forest residue chips in particular, should be so stored that it cannot contaminate the air within occupied buildings, especially hospitals and schools.

Section 5 - References

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SECTION 6

CONCLUSIONS AND RECOMMENDATIONS

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The demand for forest products throughout the world is rising at a faster rate than the supply. Much work is being done to improve productivity from the forests and develop higher value end-uses for forest and wood-processing residues. Even with these efforts, the supply of raw materials is not keeping pace with increased demand.

In the Province of New Brunswick, and in particular Forest Region 2, there is presently a substantial surplus of coniferous and deciduous harvesting residues going to waste. While in time this material may be utilized in the manufacture of wood-based products, it is available now and, if possible, should be gainfully used.

The residues for consideration are those available as slash and standing residuals from previous cuts plus that available from present cuts assuming that the residues are transported to roadside as part of the normal harvesting activity. Such would be the case for whole-tree harvesting.

In examining the potential for wood residue supply from past cuts, it was first necessary to determine the volumes, accessibility and extent of deterioration and investigate methods for efficient removal of this slash to roadside for chipping into fuel. Following the initial investigations, it was apparent that cuts more than five years old should be ignored since the on-ground residue was badly decomposed; in addition, any attempt to recover it would seriously damage the new growth. In subsequent investigations it was found that the weight of residue from one-year-old cuts was in the order of 50 tonnes/hectare, the slash from the four- and five-year-old cuts was only 25 tonnes/hectare. The slash from the two- and three-year old cuts

has deteriorated, but the decrease is not as great as that in the older cuts. In summary, with regard to slash from past cuts:

- the weight of residue material increases with increasing precut volume class, and
- the weight of residue material decreases with increasing age of cut.

The amount of residue available from slash and from the standing residual assuming a typical yearly harvest area of 8 000 hectares per year is estimated to be 375 000 oven-dry tonnes.

The cost of removing this material will vary widely with the method of removal and the amount of residue per hectare.

For clean-up, that is removal of slash and standing residual from past cuts, the cost for 80% moisture-content material prepared at roadside averages $31.85 per tonne.

On the same basis, for whole-tree chips, when obtained as part of a normal harvesting operation, the average cost is estimated to be $10/tonne, this assumes no charge for the logging activity (which stands on its own) or royalty.

For whole-tree chips, when obtained on the basis of the whole operation being dedicated to wood fuel, the costs are estimated to average $22.14/tonne (at 80% MC).

In order to determine the merits of utilizing the residue for fuel, a total of six typical applications have been investigated. Each is assumed to be using oil fuel and the wood would serve to displace, at as high a load factor as feasible, a portion of the oil. The determination of the "values" of the wood includes all costs applicable to installation of new wood-burning facilities and any additional operating costs associated with the wood-fuel handling and equipment servicing.

The calculated "value" of wood as a fuel is compared with estimated "costs" (as noted above) for preparation and supply of the wood fuel, in a series of graphs (see Graph 6.1.1 through to Graph 6.1.15 following).

The wood fuel "values" for the six typical applications are summarized in Table 4.4.1 in Section 4.4.

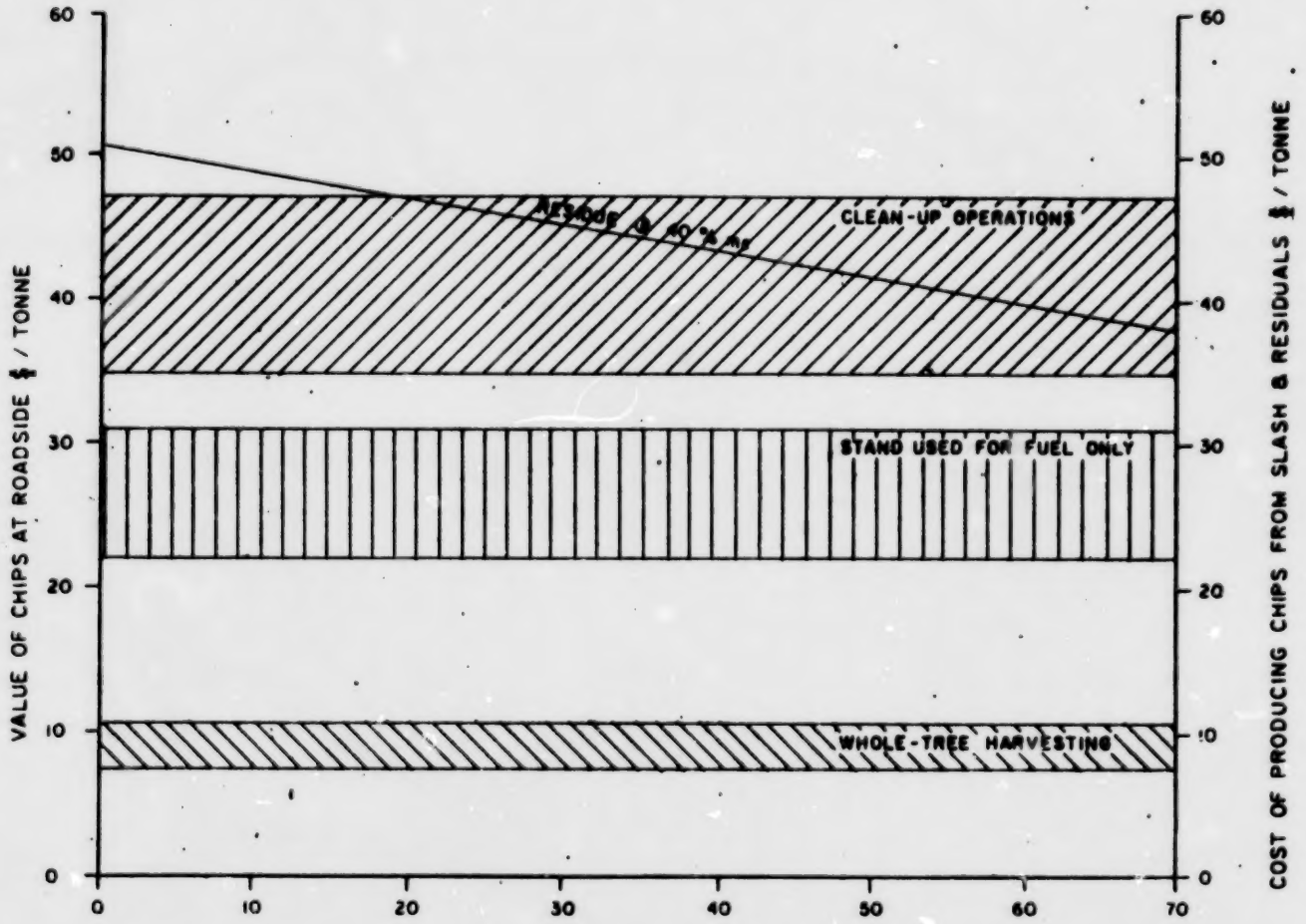
The graphs are arranged to show the "values" of the wood fuel at the consuming plant for any distance up to 70 km. Superimposed on the graph is the range of "costs", shown as horizontal cross-hatched bands, at which it is estimated the fuel can be supplied at roadside. For all "values" above the point of intersection (of "value" and "cost") the economics are not favorable for displacement of oil with wood fuel.

It will be seen from the development of "values" in Section 4.4. that the calculations are much influenced by capital cost and the write-off period. For example, the write-off period for a school or a government-owned institution has been assumed to be ten years whereas for a privately owned industrial establishment the period has been assumed to be three years. This will, in large measure, explain the large difference between the "value" at the small school of $40.13/tonne (using 80% MC wood) as compared to the "value" for the large industrial establishment of $16.56/tonne.

The following describes briefly the results available from each graph.

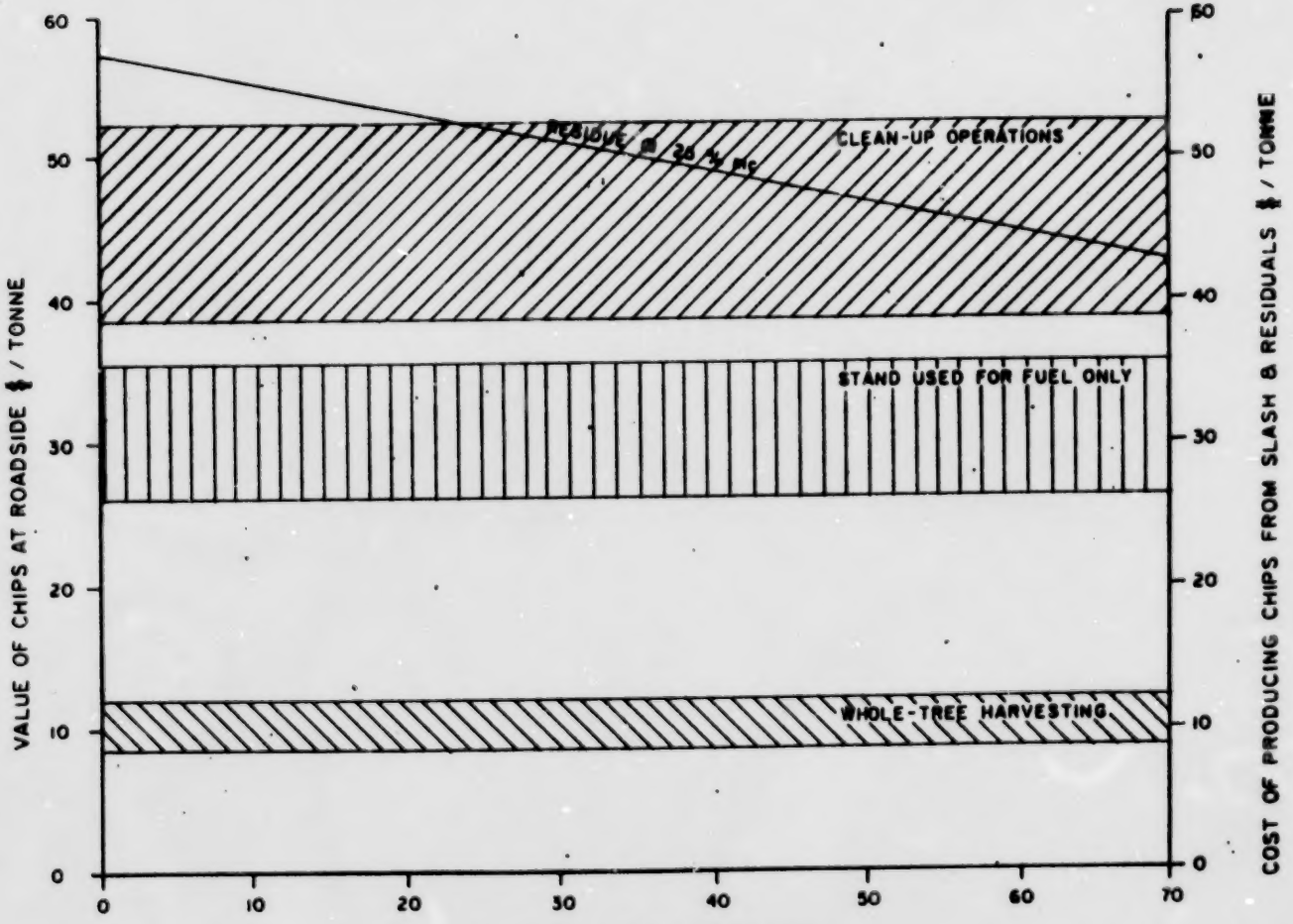
Graphs - 6.1.1 to 6.1.3 Value and Cost relationship for woodchip fuel - Small school, at moisture contents of 40%, 25% & 80%.

The small school could economically use wood fuel from whole-tree harvesting and from all of the "stands used for fuel only" up to a distance of 50 km. It must be pointed out that while



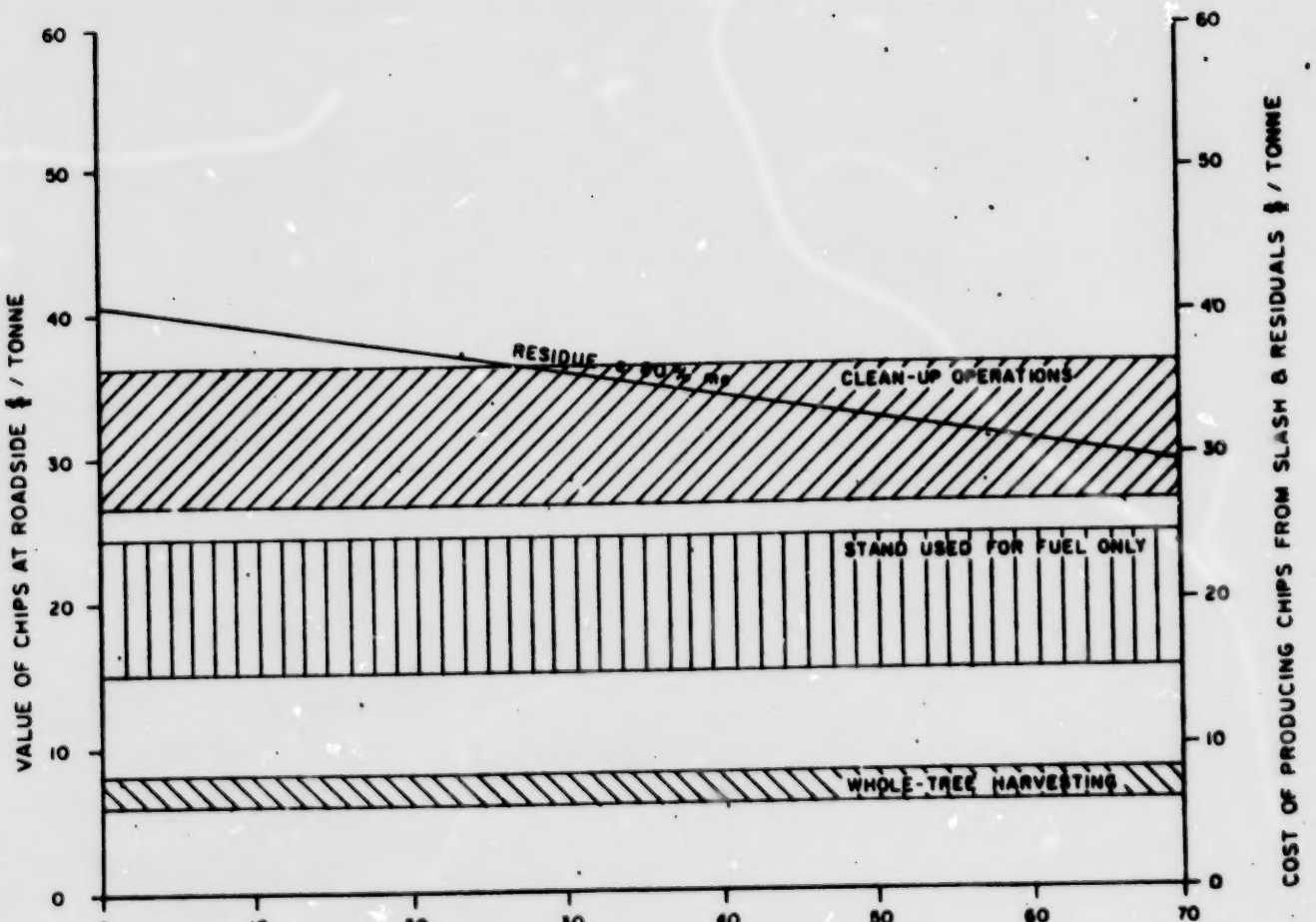
VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 40 % mc
SMALL SCHOOL

GRAPH : 6.1.1



VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 25 % mc
SMALL SCHOOL

GRAPH : 6.1.2



VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 60 % mc
SMALL SCHOOL

GRAPH : 6.1.3

this appears attractive, the quantity is relatively very small and not significant in the overall evaluation.

Graphs 6.1.4 to 6.1.6 - Value and Cost relationships for wood-chip fuel - Large school, at moisture contents of 40%, 25% and 80%

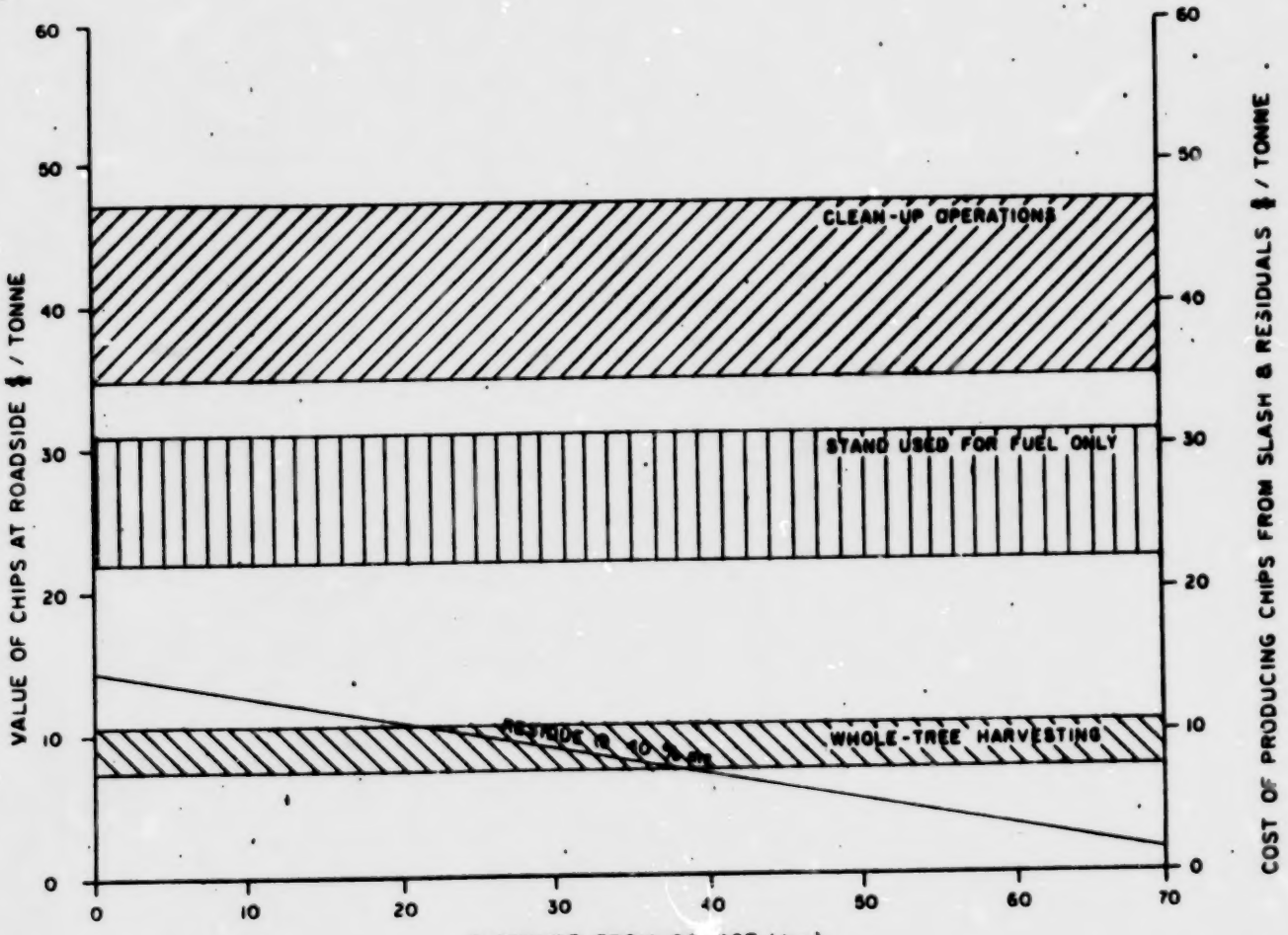
The large school could economically use wood fuel only if the residue is provided from a distance of less than 5 km and then only from a whole-tree harvesting system. One reason for this is the relatively high capital cost for assets to handle and burn the wood at a very poor load-factor. In other words, the boiler has capability to supply much more heat than the school demands.

Graphs 6.1.7 to 6.1.9 - Value and Cost relationships for wood-chip fuel - Hospital, at moisture contents of 40%, 25% and 80%.

The hospital can economically use wood fuel from a whole-tree system transported any distance up to 70km. It will be seen from the calculations in Section 4.4. earlier that a write-off period of eight years has been assumed. The improvement in this option as compared to the "large school" is due to its considerably higher load-factor. This is common at hospitals where heating loads remain high throughout the year.

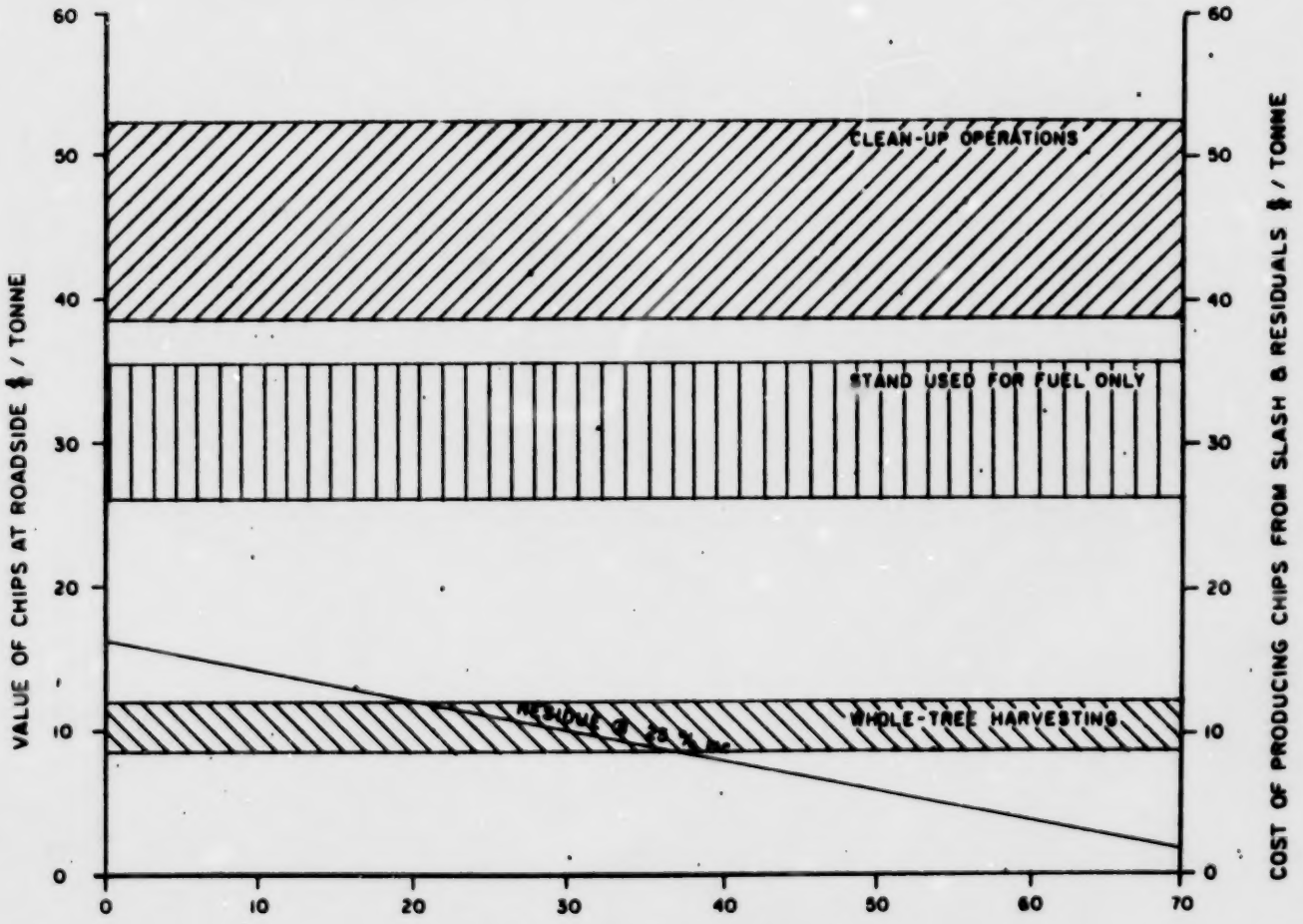
Graphs 6.1.10 to 6.1.15 - Value and Cost relationships for wood-chip fuel - Large Industrial load (having a wood-fired boiler in place) at moisture contents of 40%, 25% and 80%.

This calculation differs from the others in that no financing provision is made for capital. Instead of this, and to provide an incentive for the large industrial establishment to use wood-fuel, an allowance of 25% of the oil savings has been assigned to the establishment as profit.



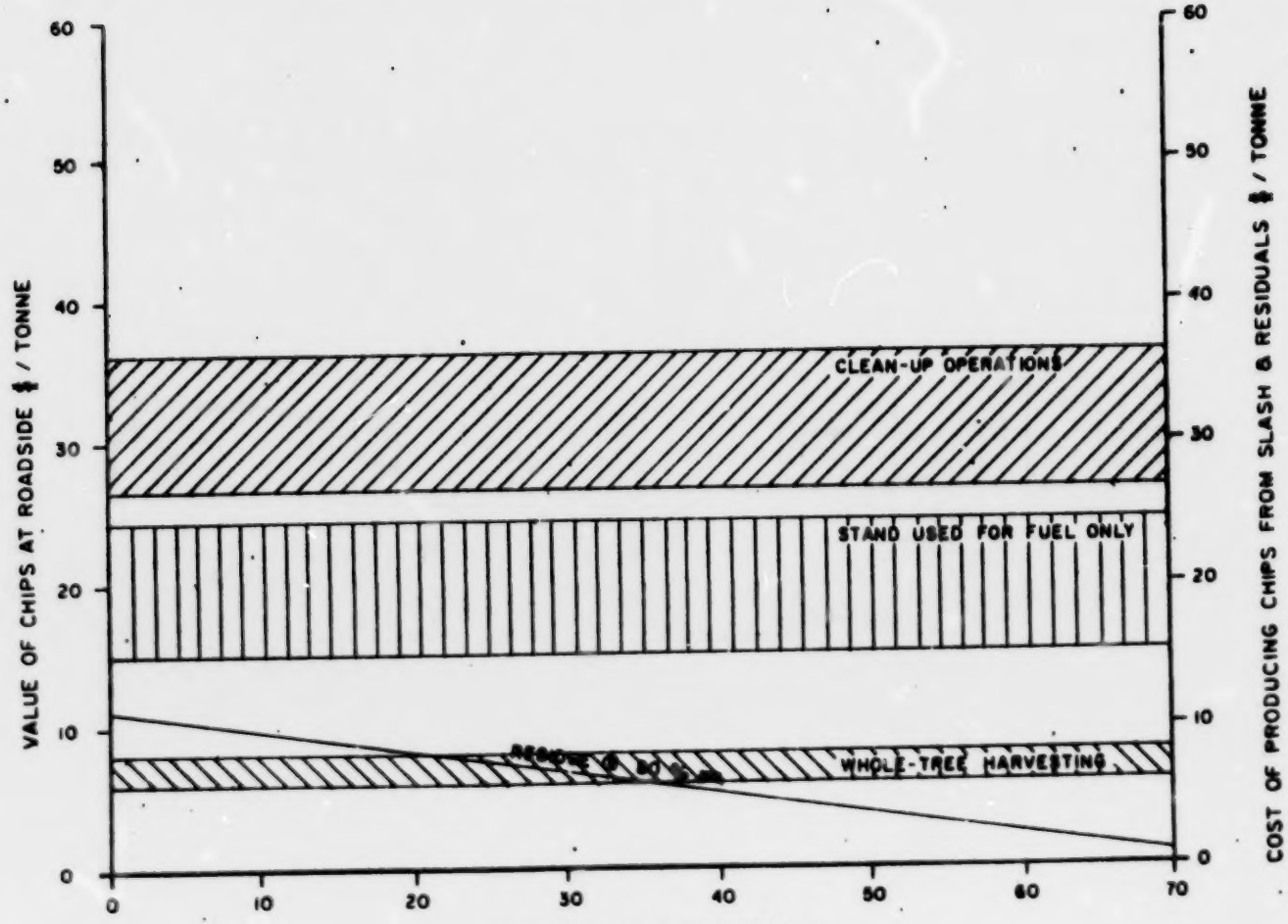
VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 40 % mc
LARGE SCHOOL

GRAPH : 6.1.4



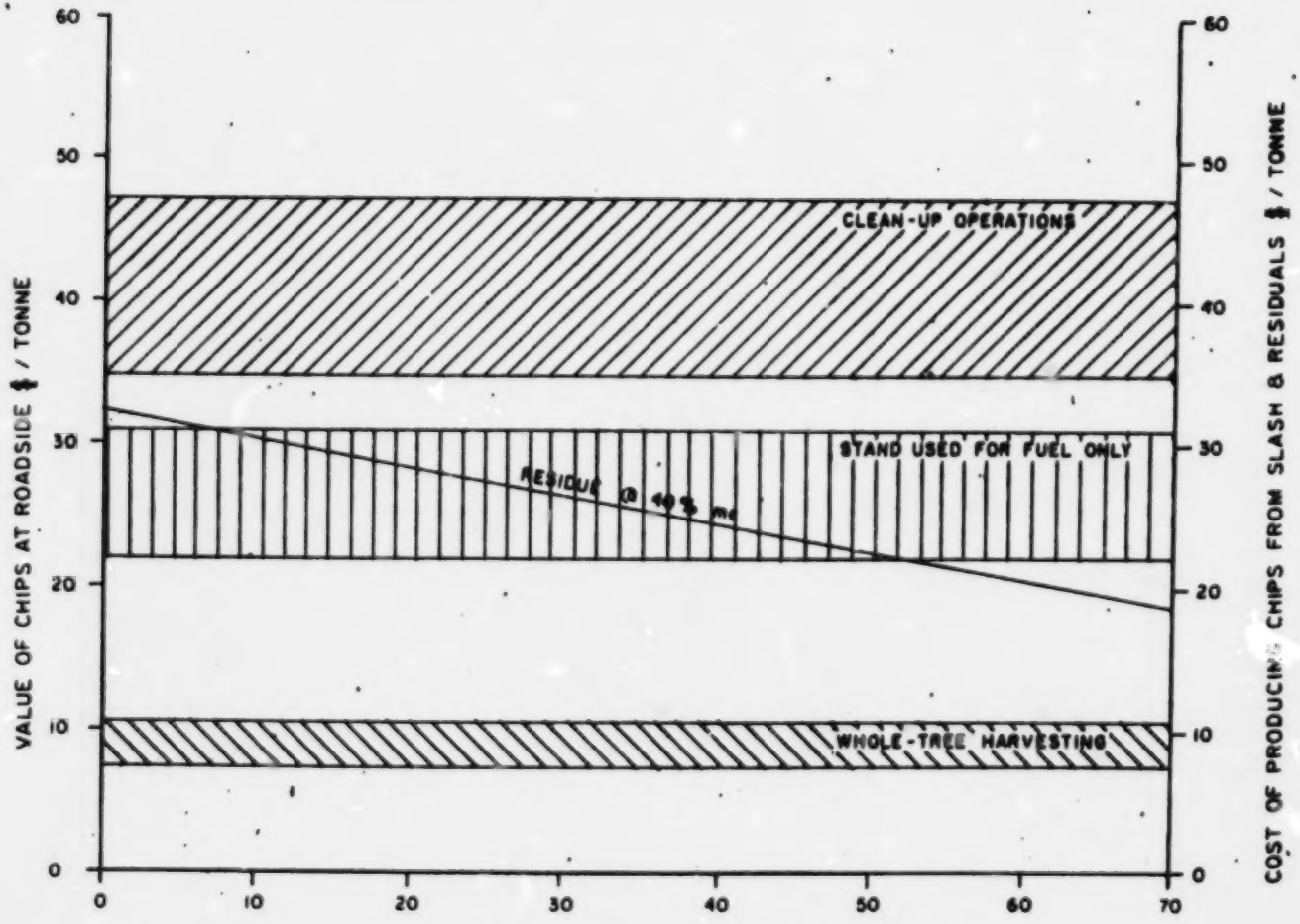
VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 25 % mc
LARGE SCHOOL

GRAPH : 6.1.5



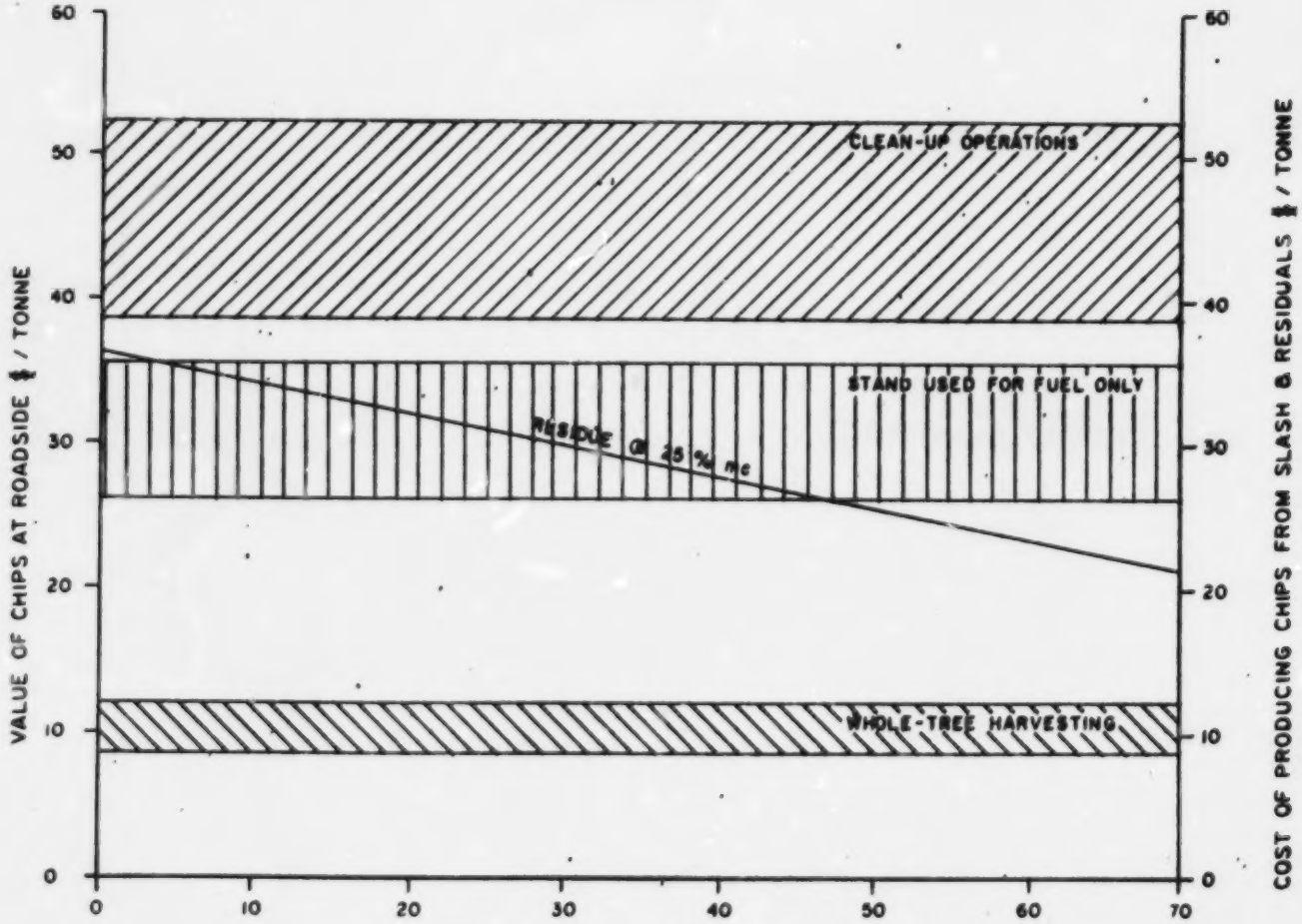
VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 80 % mc
LARGE SCHOOL

GRAPH : 6.1.6



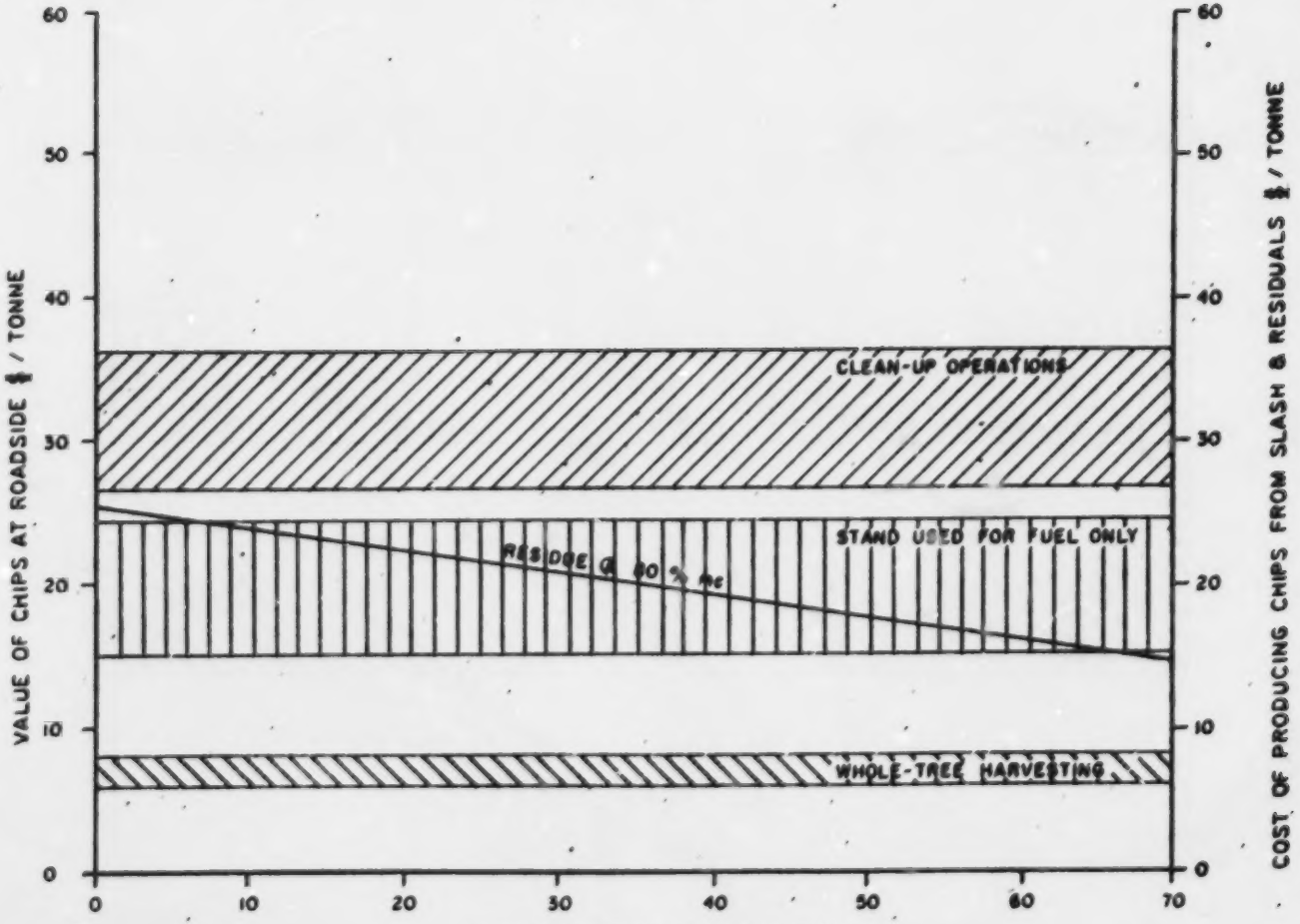
VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 40 % mc
HOSPITAL

GRAPH : 6.1.7



VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 25 % mc
HOSPITAL

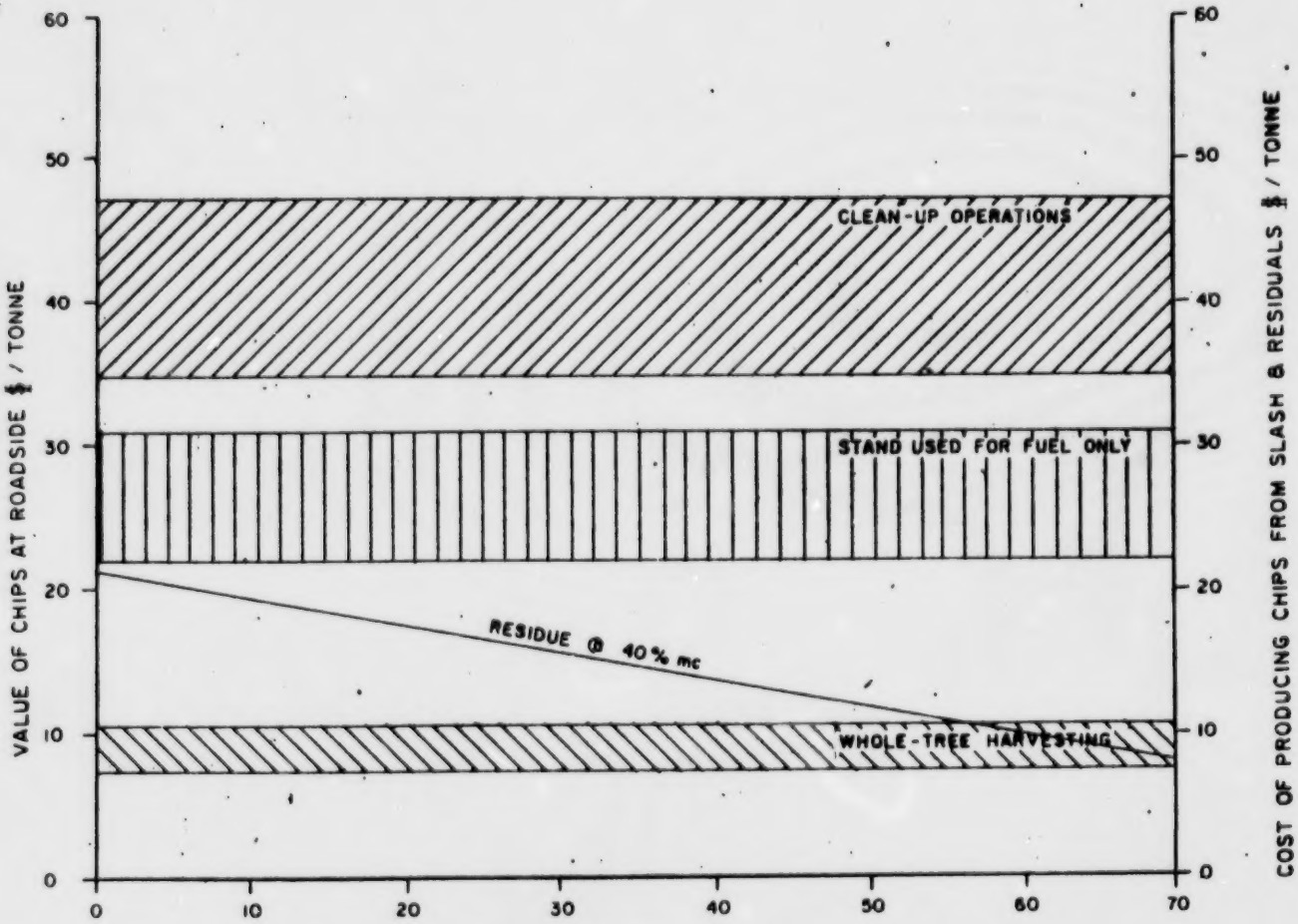
GRAPH : 8.1.8



VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 60 % mc

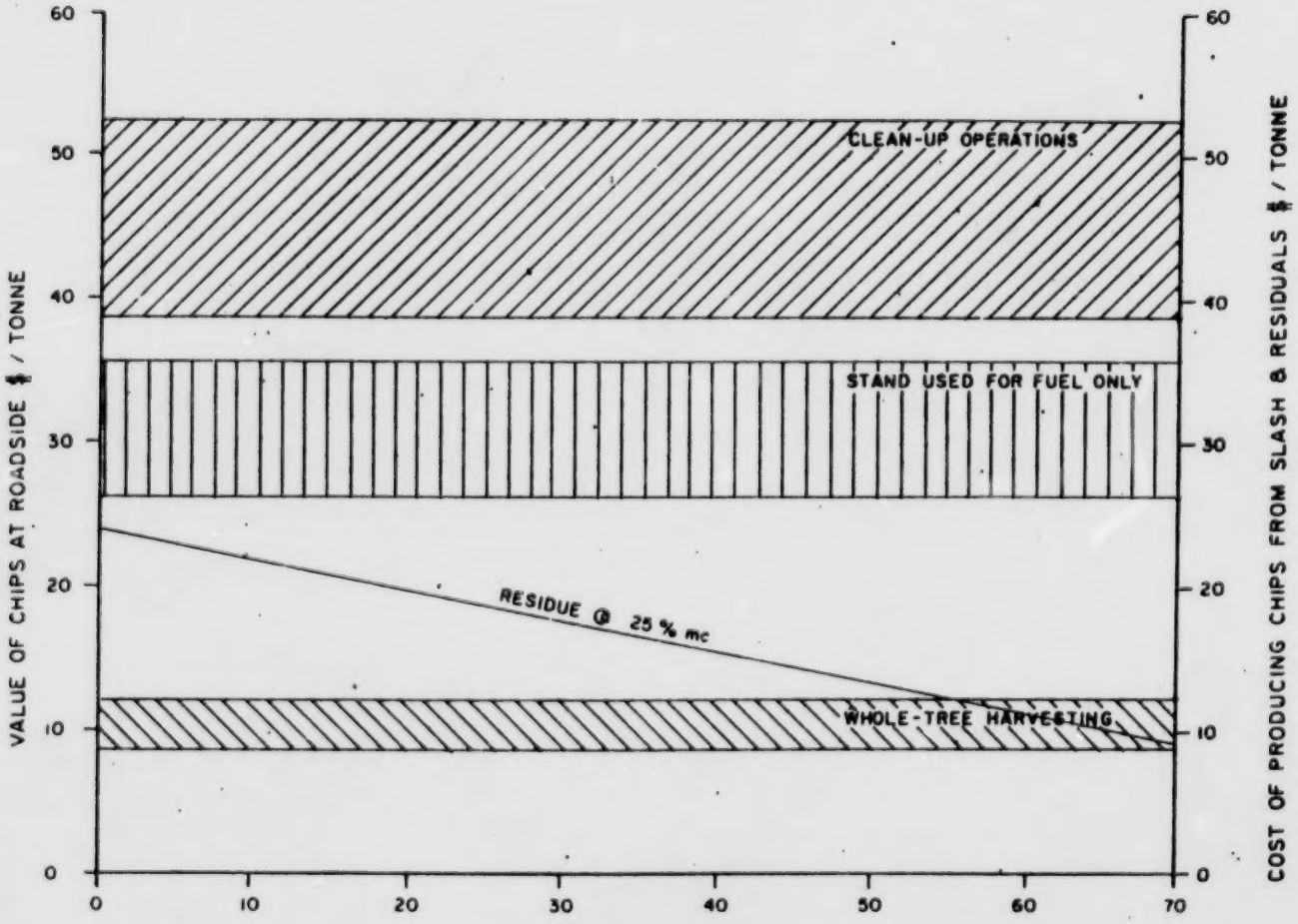
HOSPITAL

GRAPH : 6.1.9



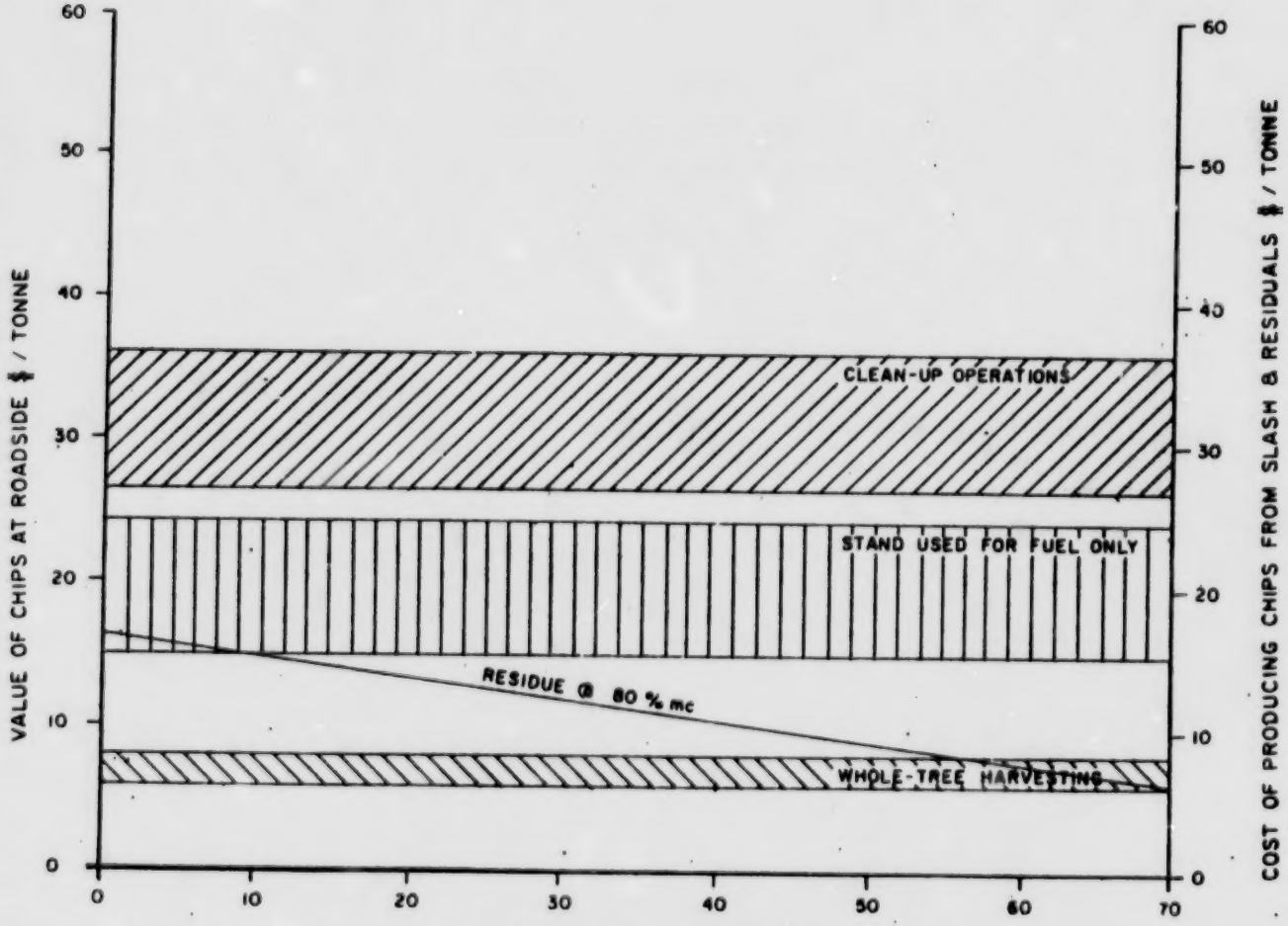
VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 40% mc
LARGE INDUSTRIAL (NEW WOOD-FIRED BOILER)

GRAPH : 6.1.10



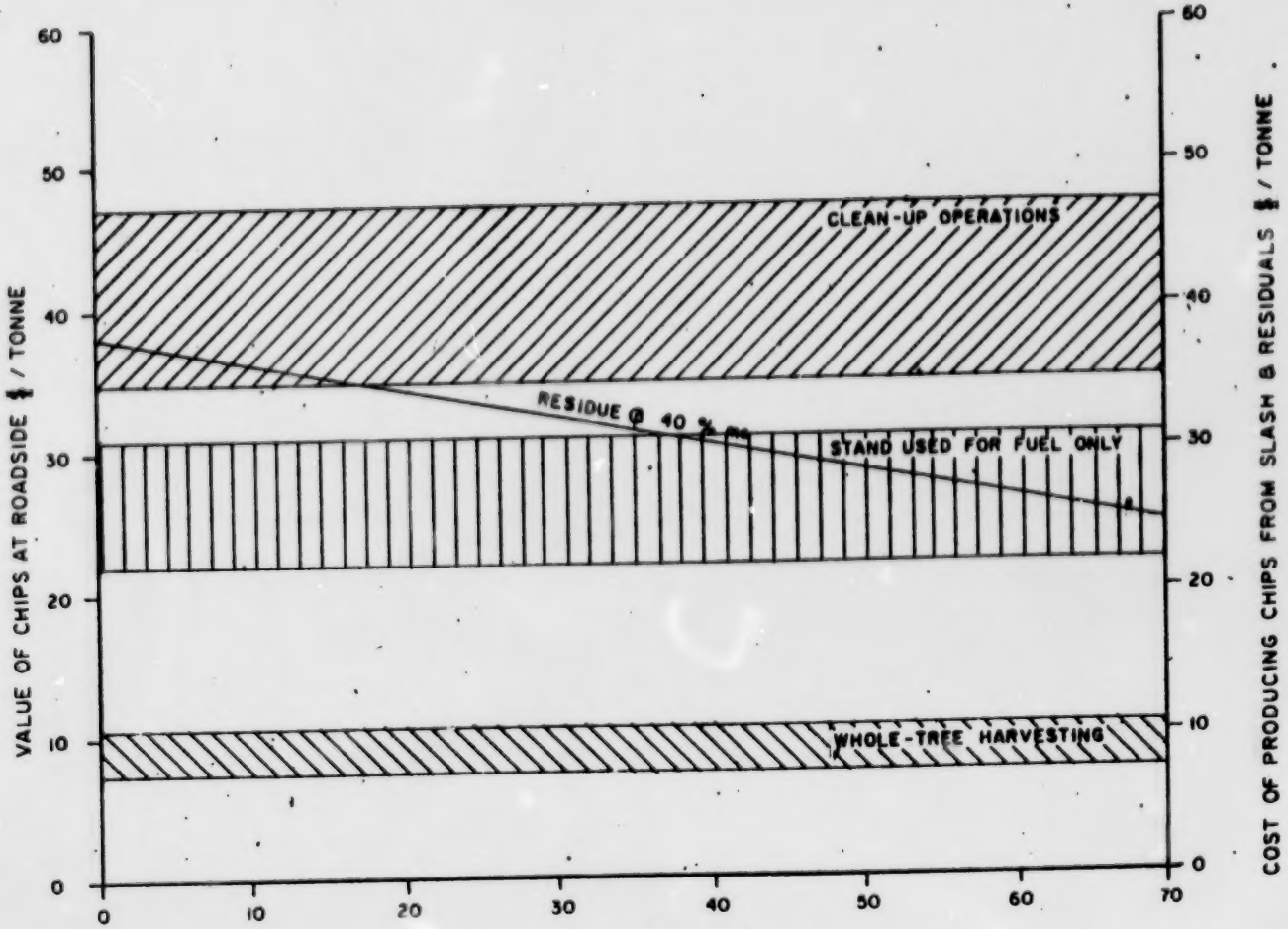
VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 25 % mc
LARGE INDUSTRIAL (NEW WOOD - FIRED BOILER)

GRAPH : 6 I.II



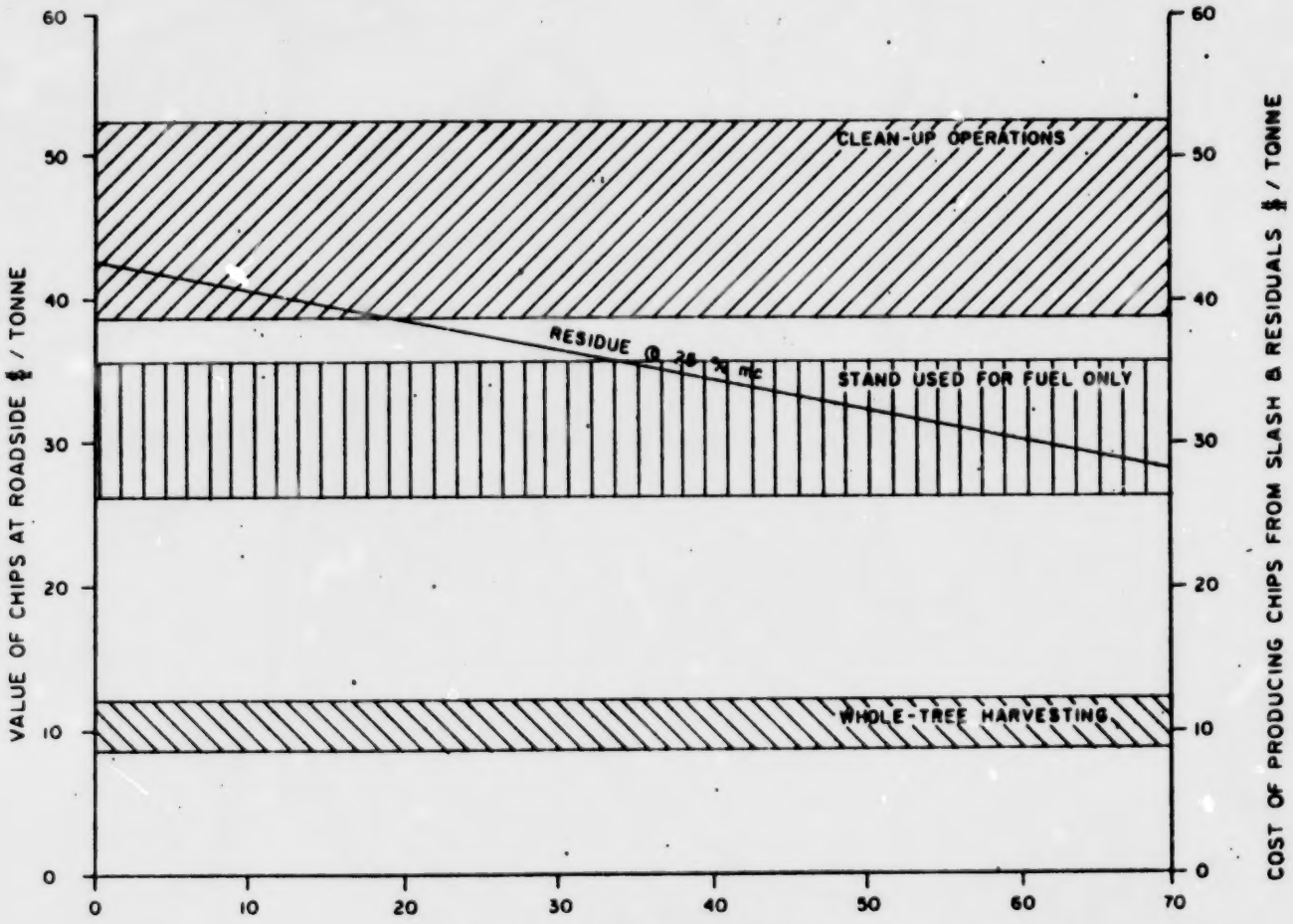
VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 80% mc
LARGE INDUSTRIAL (NEW WOOD-FIRED BOILER)

GRAPH : 6.1.12



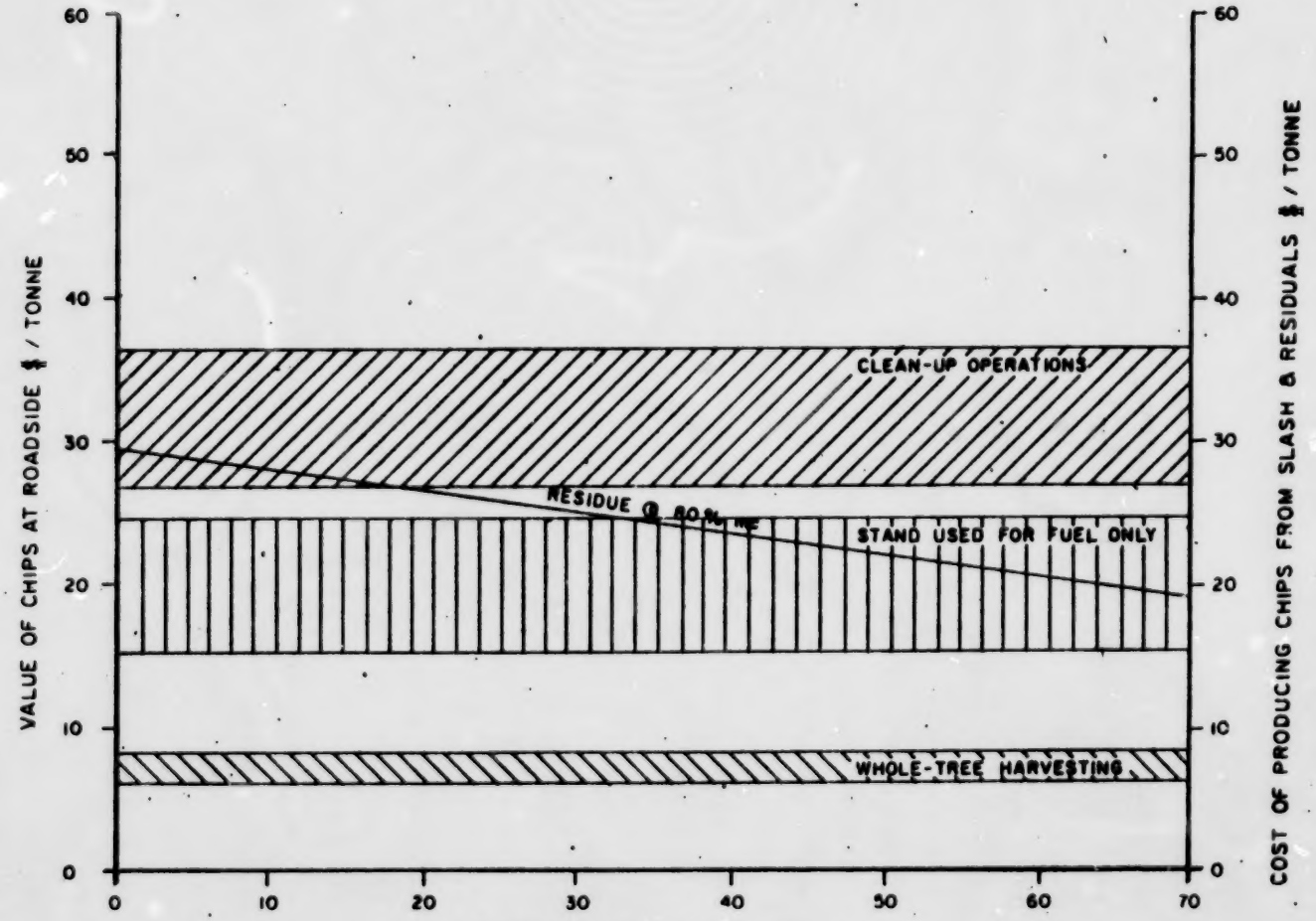
VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 40 % mc
LARGE INDUSTRIAL (WOOD-FIRED BOILER IN PLACE)

GRAPH : 6.1.13



VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 25% mc
LARGE INDUSTRIAL (WOOD-FIRED BOILER IN PLACE)

GRAPH : 6.1.14



VALUE & COST RELATIONSHIP FOR WOOD CHIP FUEL @ 80% mc
LARGE INDUSTRIAL (WOOD-FIRED BOILER IN PLACE)

Using this scenario, the application is economical for whole-tree chips up to 70 km and for "stands used for fuel only" chips provided that transport distance does not exceed an average of about 30 km.

The wood fuel is assumed to be transported in vans, although for some special applications rail cars may prove economical. The shortcoming of rail-car transport is that, if hopper cars are used allowing for quick unloading, the wood fuel is not protected from the weather and, with one or two days exposure to inclement weather, the fuel may absorb excessive moisture. Further, if box cars are used, the cost of unloading is high. Another shortcoming of this form of transport is the difficulty of monitoring loads as to weight and moisture content. There may well be applications where rail transport would prove economical and practical, but these would need to be assessed on an individual basis.

From the environmental standpoint, the removal of slash from cut-over areas removes a source of nutrients, but this is not considered very significant. Such a removal appears to be preferable to wildfire or deliberate burning as may be used for site preparation. This negative effects resulting from total removal of the woody biomass are; tendencies to soil erosion, changes in security for wildlife, a decrease in the opportunities for damaging fungal and insect attacks spawned in logging slash and a decrease in the amount of shade given the soil and seedlings.

On the positive side the removal of slash simplifies artifical regeneration with seedlings, however, with the slash left on site some protection is given to the natural regeneration of seedlings.

The environmental effects of burning wood in the home or industry are: risk of fire from build-up of smoke distillates in the chimney/stack, production of carcinogens and mutagens, and the potential for dispersion of fungus spores and hyphae in homes which may cause allergic reactions. These liabilities are not, in total, felt to be more serious than those associated with burning fossil fuels.

6.2 Recommendations

It is recommended that:

1. Encouragement be given to institutions and industrial consumers of oil fuel to convert a portion of their fuel needs to wood-chip fuel where economics of such conversions are favorable. Specifically it is recommended that;

   Small Schools - make arrangements for a test installation of wood-burning facilities at one or two schools for base-load operation.

   Large Schools - Since economics are favorable for use of wood fuel at distances up to 30 km from wood source, it is recommended that one site in this category be considered for conversion to wood fuel. There are two comparably sized institutions in the Province currently using wood fuel and it would be prudent to make reference to their experience.

Small Industry - These are not recommended for conversion unless circumstances such as high-load factor (heat) and low fuel cost (such as may apply for sawmill residue - not included in this report) apply.

Hospital - The economics are favorable for conversion to wood for base loading using whole-tree chips up to 70 km and for "fuel stand" up to 40 km. It is recommended that, one or more hospitals be encouraged to convert to wood-chip fuel.

Large Industry - The pulp and paper industry has made extensive use of wood-fuel for years and will continue to do so until such time as the value of the residue for use in their products exceeds its value for fuel. It is recommended that other large industry such as mining and the beneficiating of ore (as identified in the study) be encouraged to convert to wood fuel. The economics are favorable using whole-tree chips and under certain conditions for use of "fuel-stand" chips up to a distance of 10 km.

. Consideration be given to use of centralized distribution to schools, perhaps involving School Boards for organization and implementation.

. Initial projects should concentrate on fuel chips produced by whole-tree harvesting operations conducted with forwarders.

4. Clean-up of residue from past cuts would not often be economically feasible with conventional equipment and should be avoided except under special circumstances.

5. The performance of new equipment such as Bruks chip harvester and RECUFOR which show promise of lower production costs should be continually monitored.

6. Fuel available on cut-overs of more than two years old should not be considered as long as fresher material can be had within 70 km of the point of use.

7. Although environmental considerations will seldom be decisive factors in choosing whether or not to remove residues from harvested areas, they should always be included in the decision-making process.

APPENDIX I

WORLD SUPPLY AND DEMAND
FOREST PRODUCTS

Appendix I (i)

A. WORLD SUPPLY AND DEMAND - FOREST PRODUCTS

The principal forest products are traded on world markets. What happens to the lumber industry of Finland, or paper production in Brazil, or particleboard consumption in Japan, directly or indirectly, concerns New Brunswick forest industries. Whether the use of wood for fuel in this Province is a good short-range, medium-range or long-term proposition will largely be determined by the prospective demands of the market on the Province's forest resources. This point takes on added importance in view of the fact that softwoods are in critically short supply in New Brunswick and even the small surplus in the annual allowable cut of hardwoods may soon disappear. Thus one should be aware of the changing relationships between the world supply and the world demand for wood for all major uses in the coming decades. One should also understand the inherent value of wood for fuel as compared to its competitive values in its multitude of other uses. This appendix discusses these factors.

A.1 The Demand Side

The extraction of heat and energy from wood is but one of the wide array of uses to which this most versatile of natural products can be put. Many of its other uses are more closely linked to the conservation of energy rather than to its release. The United States, the United Kingdom, western Europe and Japan are Canada's most important markets for forest products, and New Brunswick has traditionally had a major interest in all of them except Japan. Quite recently Japan, too, has become a New Brunswick market. Although Canada is by far the world's largest exporter of woodpulp, newsprint (1) and lumber*(2), it is in keen competition with other countries, particularly in fields dominated by softwood species.

*In 1979, Canada exported almost as much lumber as the combined exports of all other countries of the world (2).

R.A. Resler, Executive Vice-President of the American Forestry Association and a retired Associate Chief of the U.S. Forest Service, speaking to the 1981 annual general meeting of the Forest Products Research Society had this to say about the ability of the United States to meet its own needs for forest products (3):

> "....I will oversimplify by stating that the Resource Planning Act Assessment indicates that the demand will more than double by the year 2030. But the expectations for increased supply from the nation's forests will only increase from 12.1 billion cubic feet in 1976 to 21.2 billion cubic feet in 2030. Thus, it is clear that imports will have to increase substantially, and the resulting increases in price for timber will dampen the demand.
>
> ....but the cold reality of our situation is that we will have to rely more heavily on imports for our wood fiber needs beyond the turn of the century in an international trade situation in which the dollar may well be less competitive unless some aggressive actions are taken in the near future."

Two other American authorities (Darr and Lindell)(4) had these comments in 1980:

> "Imports of softwood lumber are expected to follow a similar pattern increasing to a maximum of 13.5 billion board feet in 1990 (from a level of 10.4 billion board feet in 1976, ESF) and amounting to about 28 percent of U.S. consumption.
>
> Imports of wood pulp into the United States have grown slowly over the past 2 decades, and we expect continued growth throughout the prediction period. Canada is currently the source for about 95 percent of U.S. imports, and we expect Canadian sources to dominate this portion of the trade."

> "Currently, U.S. consumers take about 72 percent of Canadian production of newsprint ..... The expansion of newsprint production expected in the United States will probably tend to make Canadian producers concentrate more on offshore markets, especially Western Europe. Nonetheless, the projections indicate that Canadian producers will have an expanding U.S. market over the coming decades."

The roundwood equivalent of the United States imports of forest products amounted to about 280 million m^3 in 1950, 396 million m^3 in 1978, and are forecast to rise to 643 million m^3 by the year 2000 and to more than 801 million m^3 by 2030(5).

At the 1978 annual general meeting of the Commonwealth Forestry Association, T.J. Peck, Chief of the Timber Section of FAO/ECE Agriculture and Timber Division, discussed his organization's assessment of European consumption of forest products to the end of this century. In the course of his address he made the following comments (6):

> "For forest products in total, the trend has been for Europe's self-sufficiency to decline. In 1950, its imports and exports more or less balanced, but since then, growth in imports has outstripped that of exports, so that by 1960 net imports accounted for 4½% of consumption, in 1970 for 10% and in the mid-1970's for an estimated 11½%. The ETTS III* forecast of net imports of 115 million m^3 EQ** in the year 2000 is a continuation of this trend, giving net imports a nearly 15% share of Europe's consumption by the end of the century."

---

*"ETTS III" is the official abbreviation for "European Timber Trends and Prospects, 1950 to 2000" prepared and published by the Food and Agriculture Organization and the Economic Commission for Europe, both organizations being agencies of the United Nations.

**EQ means equivalent quantity in terms of roundwood required to produce the manufactured products.

> "....All members of the European Economic Community (EEC) are substantial importers of forest products, even the relatively well forested countries such as France and the Federal Republic of Germany. The United Kingdom alone, with net imports of 37 million m^3 EQ in 1974-76, made up one-third of the EEC's total volume of net imports."

Mr. Peck said that, by the year 2000, Europe's total consumption of forest products is forecast to be 75 percent higher than it was in the mid-1970's. During the same period, North American exports of forest products to Europe are projected to double.

Five years earlier, R.C. Stern, of the Harvesting and Marketing Division of the British Forestry Commission, had predicted somewhat higher net timber imports into the United Kingdom by the year 1975 (namely, 42.5 million m^3) than actually occurred (7). However, this does not seriously fault his projection of a shortfall of 63.5 million m^3 between British consumption and domestic production by the year 2000.

In 1960, Japan imported 7.7 million m^3 of timber. By 1978, this figure had increased to 71 million m^3, and the country was producing only 30 percent of its timber needs (8). In the late 1970's, Japan produced 9.1 million tonnes of pulp from domestic raw materials, but consumption stood at 14.1 million tonnes. In recent years, there has been a sharp increase in the use of tropical hardwoods for pulp, but conifers -- largely from America and Siberia -- still constitute more than two-thirds of the furnish (9). It is expected that Japan's domestic wood production will double from 46.3 million m^3 in 1971 to 94.3 million m^3 in 2031 and thus ease the demand for foreign raw material. However, imports are expected to grow and the country will remain in a strongly deficit position with respect to wood supplies at least until the end of this century (10).

In the world as a whole, sawlog and veneer log production is anticipated to increase by 1.3 percent per year, with lumber output increasing by only about 1.0 percent per year. In contrast, wood-based panelboard production is expected to increase at an annual rate of three percent, and paper and paperboard output by almost 4 percent. The use of fuelwood worldwide is estimated to increase at only about ½ of 1 percent per year, but this is due entirely to a much greater rate of increase in developing countries being offset in part by decreasing use in the rest of the world. In 1974, about 47 percent of the world production of roundwood was consumed as fuel. Generally speaking, the world production of industrial roundwood is forecast to reach 2 508 million m^3 by the year 2000 -- almost double the 1974 harvest of 1 341 million m^3. In short, the world demand for roundwood for all uses, including fuel, is projected to increase from 2 511 million m^3 in 1974 to 3 800 million m^3 by 2000 -- a rise of 51 percent in a quarter of a century (11).

To give local point to this picture of fast-rising demand for wood fibre, the reader is reminded that the industrial use of low-grade hardwood in New Brunswick in the late 1960's was less than 85 000 m^3 per year. By the late 1970's the corresponding figure was more than 1 100 000 m^3 -- a thirteen-fold increase in a decade.

A.2 The Supply Side

It can be inferred from what has been said about the demands for forest products that supplies of raw materials in some of the developed countries at least are not keeping pace with increased demands. This is particularly true of Canada's principal customers for wood products, namely, the United States, the United Kingdom, Western Europe and Japan. Of course, all of

these countries are striving to increase their domestic forest resources. The United States has plans to raise its annual domestic supplies of softwoods from 269 million m^3 in 1976 to 348 million m^3 by the year 2030. A corresponding rise from 95 million m^3 to 252 million m^3 is forecast for the annual production of hardwoods (5). The United Kingdom anticipates its annual timber harvest will rise from about 4.5 million m^3 in 1975 to about 11.5 million m^3 by the year 2000 (7).

Western Europe's forest harvests are projected to rise to an annual level of between 383 and 455 million m^3 in 2000 as compared to about 337 million m^3 at the beginning of the 1970's (6). The Government of Japan plans to increase its domestic supply of industrial wood from the 1971 level of 46.3 million m^3 to 94.3 million m^3 by the year 2031 (10). Yet, in all these cases, the spread between domestic production and total consumption is expected to increase and to be met by importations.

There are vast unused forest resources in the rain forests of the Amazon and the Congo, but these are known to be fragile ecosystems. Some scientists and others believe they are already being exploited to a very dangerous degree and may even disappear almost entirely in less than half a century (12), if the rate at which they are being destroyed is not drastically slowed.

It is a well-known fact that other areas of tropical forests in the southwest Pacific and southeast Asia are also being heavily exploited for both fuel and industrial wood.

For the past several years, Canadians have been constantly reminded that raw material demands of their forest industries are outstripping the current ability of the forests to continue suppling. Even though major efforts and much more funding are being directed towards increasing the productivity of the forests, the margin for Canadian forest industries to expand during the next several decades is slim indeed and much of it is geographically remote. New Brunswick shares in this situation, although here the problem is compounded by the long-continuing spruce-budworm infestation. What little portion of the Canadian annual allowable timber harvest still remains is largely in the deciduous species; this is now entirely the case in New Brunswick.

This leaves the Soviet Union as the only country in the world with extensive coniferous forests which have not yet been fully exploited. Yet, on the best available authority, the USSR's exportable surplus of timber is probably far smaller than many people believe, although it must be admitted that this subject is something of an enigma. We cannot do better than to quote from an exhaustive, 1975 article by Mr. W.R.J. Sutton, a New Zealand Forest Economist, on this subject (13).

> "Contrary to popular belief the USSR appears not to possess a vast underutilized forest resource of high quality. By area and volume the potentially exploitable forests of the USSR are comparable to the combined resources of Canada and the USA. The total increment is comparable to that of the USA alone.

The total annual cut is estimated to be already very near to the total annual increment of the exploitable forests. Over exploitation has been, and still is, continuing in the Scots pine and spruce forests of Western USSR, and, much of the felled forest has failed to regenerate adequately. Future industrial expansion is only possible in the predominantly larch forest of Eastern Siberia and the Far East, and, in non-conifer species (mainly birch).

Because of increasing internal demand, increased future exports from the USSR may not be possible. Despite considerable expansion of particle-board plants and pulp and paper mills, future exports may not increase because of the rise in internal demand. The supply situation for coniferous sawn timber will be most critical, -- the USSR has no plans for large scale expansion of this industry. If exports are possible they are likely to be expensive.

Major importing countries, such as Britain, may have problems securing future supplies especially of coniferous sawn timber.

This study suggests that the USSR has limited scope for increased exports, and even if there is any surplus it will only be in the region of Eastern Siberia and the Far East and in low quality species of larch and birch. Europe is already deficient and the major exporters within Europe (Finland and Sweden) have limited scope for increased production; indeed, because of possible overcutting, some reduction in production may even be necessary. North America too is likely to become a potentially deficient region. The expected surplus production in Canada by the year 2000 is of the order of the expected deficiency of the USA. There too it is the supply of sawn timber that is going to be most critical."

From all of the foregoing, the inescapable conclusion is that the overall relationship between the timber supply and demand during the next 40 or 50 years is likely to be one of a rapidly diminishing and finally vanishing surplus of round coniferous timber. This will probably be offset in part by sharply broadened standards of utilization (the use of mill and forest residues) and the substitution of deciduous species for coniferous ones wherever feasible. There may even be doubt that there will be enough timber of <u>all</u> species to satisfy the world's needs for industrial wood and fuel by the year 2000 and for at least a few decades beyond that.

However, at the present time in New Brunswick there are large quantities of unused coniferous and deciduous harvesting residues, there are stands of low-grade hardwood and mixedwood which cannot be economically harvested for their so-called "merchantable wood" content alone, and there are probably very limited quantities of manufacturing residues (sawdust, shavings, and small cuttings) which are not being used. The question is: What use might be made of these residues and unused resources in the short run, and are there likely to be conflicts between short-run and long-term utilization policies?

It is in this context that we examine the options which are open now, and in the near future, for putting the world's limited annual harvest of wood to uses which are in the best interests of society.

A.3 <u>The Demand Options</u>

The wood biomass now unused in New Brunswick takes the form of manufacturing residues (sawdust, shavings, bark and trimmings from lumber, plywood, flakeboard and particleboard), harvesting residues (chiefly tree tops and large branches), and standing

timber of no manufacturing value because of species, size, form or soundness. All of these materials -- even bark -- do find manufacturing uses somewhere, but present markets are relatively small and scattered. But, as pressure on limited timber resources continues to grow, there will be increasing demands for such materials. Some or all of these classes of waste can be used in the manufacture of several kinds of pulp, fibreboards, particleboards and molded products; in the production of chemicals, such as methanol, ethanol, furfural, phenol and formaldehyde; in the manufacture of cattle fodder; and for fuel in various forms -- "chunk" wood, comminuted wood (hogged woood or chips), briquettes or pellets, charcoal or wood gas. Of course, there are advantages, disadvantages and limitations in the use of residues for most, if not all, of these uses. The pros and cons of residues as manufacturing raw material or as fuel may be summarized as follows.

Wood Pulp

The use of whole-tree chips for the manufacture of pulp has been undergoing study and tests for more than a decade. In an article published in 1972 (14), the author stated that "it must be concluded that rough wood* pulping by the kraft process has economic advantages in addition to being the most viable procedure for extending our wood resources". Eight years later, Jan Temler stated (15) that whole-tree chips have a high potential for hardwood kraft, hardwood semi-chemical pulp and high-yield softwood kraft; a medium potential for unbleached, softwood, low-yield pulp; a low potential for bleached, low-yield softwood pulp (continuous digester process) and a very low potential for bisulphite pulp and thermo-mechanical pulp.

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*"Rough wood" means wood with bark attached.

While even today the use of whole-tree chips cannot be said to be a widespread practice in the pulp industry, it has gone far beyond the laboratory or pilot-plant scale. In 1980, one Canadian company planned to use 135 000 oven-dry tonnes of such material in four of its pulpmills (16). There are, of course, serious disadvantages in the use of whole-tree chips, chief amongst them being the difficulty of lowering the bark content to acceptable levels, inferior pulp qualities resulting from the use of foliage, twigs and small branches (juvenile wood), decreased digester loads, increased use of alkali, increased black liquor production, and increased problems in bleaching (17). However, processes are being evolved to reduce the problems with bark (18), foliage and twigs (16, 18). Whole-tree chips are said to involve 33 to 50 percent less woods labour, reduced injuries to woods workers, reduced transportation costs, shorter delivery times, reduced forest-fire hazard, aesthetically improved harvested areas, improved and lower-cost forest regeneration, make otherwise unprofitable forest stands "operable", somewhat reduce pulp cooking-time and, above all, increase the yield of fibre from a given area by 30 to 40 percent. These facts go a long way to offset, or completely cancel out, the disadvantages noted above (16, 17).

It has even been suggested that, by going to whole-tree chipping of young stands (say, ten years old), a pulp mill of a given size could operate with only about 15 percent of its present land-base needs (19). This may be unduly optimistic, but it is certainly indicative of what may lie ahead.

Panelboards

Panelboards represent one of the fastest-growing segments of the world-wide forest products industries. In the huge United States and European markets they are expected to be in the fastest-growing segment. Consumption of hardboard in the United States is projected to rise by 68 percent between 1976 and 1990, and the consumption of particleboard to rise by 91 percent in the same period. Somewhat smaller rates of increase are projected for plywood, while insulating board is expected to increase only very slowly (12.5%) (20). In terms of absolute quantities, however, the United States consumption of all kinds of panelboards is projected to increase from a grand total of 30.0 million cubic metres in 1976 to 45.6 million cubic metres in 1990 -- a rise of 52 percent. It is expected that the consumption of panelboards in Europe will increase six-fold during the last 30 years of this century (6).

Some panelboards are made chiefly or exclusively from bark, but such panels are not intended for uses where strength is a prime requirement. In general, however, it is the presence of bark, branch wood and badly decayed wood which are the chief deterrents to the use of whole-tree chips in the manufacture of particleboards and flakeboards (21). Even for panelboards made by the wet or semi-dry processes, bark is undesirable because of problems it creates in the process of reducing the wood particles to fibre and, to a lesser degree, to the darker color given to the board by the inclusion of bark (22). But just as in the case of the pulping of whole-tree chips, methods for reducing the proportions of bark and of foliage and twigs are being developed. Progress is also being made toward overcoming certain manufacturing problems in the formation of the fibre or particle mats which are pressed into panels. The incentive to

find solutions to these problems is, as before, the goal of developing more plentiful supplies of raw material. This search for new sources of material for panelboards gets added impetus from the fact that traditional sources of wood residues are tending to either (i) dry up as wood-processing plants (e.g., sawmills and veneer mills) improve their machines and techniques, or (ii) be used by woodpulp industries which can afford to pay higher prices (23). Indeed, as Stone and McSwain succinctly point out (20): "Moves into new panel materials have been evolutionary rather than revolutionary and have been mainly spurred by the need to utilize raw materials more efficiently, ...".

Chemicals

At the instigation of the National Science Foundation and the Federal Energy Administration of the United States, the U.S. Forest Products Laboratory in the mid-1970's commissioned the firm of Raphael Katzen and Associates to make a comprehensive study of the chemical aspects of the feasibility of using forest residues for energy and chemicals. The findings of this study, as summarized by Jerome F. Saeman (24), form the basis of this section of our report.

The Katzen report dealt with the technologies and economic feasibility of producing sugar, ethanol and furfural, in discrete operations, and ethanol, furfural and phenol in a combined production facility. Two basic assumptions used throughout the study were that the costs of wood delivered to the appropriate plant would be either $24 or $34 per oven-dry ton (odt), and that an after-tax profit of 15 percent be required. The wood price of $24/ton was considered the minimum cost in 1975 at which chemical use of wood could compete with its use as fuel. At the same time, the corresponding prices for

pulpwood ranged between $40 and $60 per odt (25). One cannot, of course, transpose the detailed results of such a study from one country to another. However, at that time the average value of softwood pulpwood in Canada was about $45.50 per cord* (sawmill chips $38.75 per cord equivalent) and U.S. and Canadian currencies were virtually at par, so it seems quite reasonable to assume the broad conclusions of this particular investigation were applicable on both sides of the border.

The following are the basic findings of the Katzen study.

Sugar

On the basis of a plant producing 180 000 tons of sugar per year (roughly 500 tons/day), wood requirements would be 1 480 odt per day -- approximately the same volume as would be required to supply a 600 ton/day bleached-kraft pulpmill. Allowing for a 15 percent after-tax profit on investment, the sugar produced would have to sell for 13.4 cents per pound to make the process commercially viable. At that time, sugar in the form of molasses (a comparable end-product) was selling for 5.5 cents per pound.

Quadrupling the size of the plant to gain the economies of scale, brought the selling price at the 15 percent-profile level down to 9.6 cents per pound with the price of raw material remaining at $34 odt. However, with wood consumption at 6 000 odt/day, the land-base needs of such a plant would be so large that increased raw material transportation costs would eat up much of the economies of scale gained in the manufacturing phase. The obvious conclusion seems to be that the commercial production of sugar from wood in a single-purpose plant is not a probability in the foreseeable future.

*A cord of typical softwood pulpwood in New Brunswick has an oven-dry weight of about 0.95 of a ton. (0.86 of a tonne).

Ethanol

Ethanol (otherwise known as ethyl alcohol) is usually made from ethylene or grain, but can be made from wood. It was estimated that a plant producing 25 000 000 U.S. gallons (US gal.) per year from ethylene priced at 11 cents per pound would cost about $20 million to put into operation and could produce a product to sell at $0.91 per US gal. A similar size of plant using grain priced at $3.00 per bushel as feed stock would cost about $5 million more and its output would have to sell at $1.43/U.S. gal to yield 15 percent after-tax profit. A comparable plant using "waste" wood was estimated to cost about $70 million and would have to sell its product at $1.90/US gal. to return the same rate of profit. Such a plant would need 1 480 odt/day of wood raw material. There were modest economies of scale in manufacturing costs when plants of 100 million gallons a year were considered, but the relative merits of the three forms of raw material were very little changed. Again, of course, the logistics of collecting 6 000 odt of wood "waste" every day at one plant are formidable. In this case also the relative prices of the three forms of raw material considered would have to change quite drastically before wood could become a competitive feedstock.

Furfural

In Europe some furfural is made from birch wood, but in the United States it is currently made exclusively from agricultural wastes.

The Katzen study indicated that a single-purpose plant producing furfural from wood would not be competitive. At the same assumed cost of wood, a plant producing as much as 40 million pounds per year would have to sell its product at 50 percent above the going market price to achieve the aim of a 15 percent after-tax profit.

Multiproduct Plants

The Katzen study investigated the concept of multiproduct plants using either softwoods or hardwoods to make ethanol, furfural and phenol, with the size being linked to an output of 25 or 50 million US gal. of ethanol per year.

Both levels of production and both types of raw material produced results which indicated selling prices much closer to competitive levels than any of the single-purpose plants studied. The plant using hardwoods indicated the better results, chiefly because of the higher yield of furfural obtainable from hardwoods. However, no combination of plant size and raw material indicated a genuinely competitive position vis-à-vis present practices. Furthermore, at the higher level of production (lower level of unit costs), the problems of collecting the required quantities of wood at a given site and of marketing the furfural produced placed the practicality of such a plant in very serious doubt even if, on paper, the cost/price analysis were sound. It was noted that a 50-million-gallon-per-year plant would produce a quantity of furfural amounting to about two-thirds of the then-current, total United States demand.

A further significant factor is that the proportions of ethanol, furfural and phenol produced are a fixed function of the raw material used, and hence the ratios of production cannot be altered to suit changing market demands.

Methanol

For years there has been much discussion of the production of methanol (otherwise known as "wood alcohol") from wood to be blended with gasoline to make "gasohol" as part of the effort to conserve petroleum.

On this continent, methanol is made from natural gas (of which Canada has a very large exportable surplus) and from oilrefinery light-gas streams. In 1975, the price of methanol in tank-car lots at U.S. Gulf Coast sites was 38 cents per US gal. At the request of the National Science Foundation and the Federal Energy Administration, the U.S. Forest Products Laboratory undertook a study in 1976/77 of the economic feasibility of making methanol from "waste" wood. A report on that study (25) concluded that a plant in the United States to produce 50 million US gal. per year of methanol from "waste" wood would cost $64 million to put into operation and that its product would have to sell for 96 cents per gallon to achieve an after-tax profit of 15 percent on investment.

It should be noted that a plant capable of producing 50 million gallons of methanol per year would have wood requirements similar in volume to those of an 800 ton/day chemical-pulp mill. It is also worth noting that the energy represented by a gallon of methanol is only 38 percent of the energy input into the process in the form of raw material and external energy input, or about half the energy inherent in the wood used to produce the end-product.

In the overall economic analysis of the three types of raw material considered natural gas was ranked as the most desirable, coal in the intermediate position and wood as the least efficient.

On the subject of producing chemicals from "waste" wood, Saeman's generalized conclusion based on the Katzen study is as follows (24):

> "It is a safe generalization to say that for the next decade at least, the most efficient way to use wood as a source of gas or liquid fuels will be to divert such fossil fuels from furnaces and burn wood instead. With rare exceptions, organic chemicals can be made more efficiently from petroleum saved by burning wood than directly from wood itself."

-- but his final observation is intriguing --

> "Some new technique which inexpensively accomplishes the hydrolysis of cellulose to glucose would be of immense significance in solving world food and energy problems."

Animal Food

Wood can be used as a raw material in making animal food in at least two ways. First, by saccharification in which the wood is hydrolyzed to produce sugar solutions which are then concentrated by evaporation to produce "wood molasses". The molasses is mixed with other feed stuffs in various ratios up to 20 percent or so, which can then be fed to cattle, sheep, swine and poultry. It appears to be as acceptable and as nutritional as cane-sugar molasses.

It is also technically feasible to ferment the wood-sugar solutions to obtain ethyl alcohol and yeast, the latter being a very good source of protein and vitamins of the B-complex as a cattle ration.

The second method of using wood as animal feed is by treating finely comminuted wood of certain deciduous species, notably aspen, with dilute alkali or anhydrous ammonia to render it

partially digestible by ruminant animals. The nutritional value of this form of fodder is said to be roughly equivalent to that of medium-quality hay, but it is a good source of roughage which is essential in the diet of ruminants (26).

None of these processes has yet become economically feasible, but they are not very far off that target.

Fuel

The fuel value of a given weight of moisture-free wood varies very little with species, although woods with a relatively high content of resins or oils may be slightly higher than others in average calorific value. Moisture-free, nonresinous woods in otherwise natural condition are usually considered to have a fuel value of about 19.77 MJ/kg (8 500 Btu's per pound). Bark is usually considered to have approximately the same fuel value as wood, other conditions being the same.

So long as moisture-free wood has nothing added to it or taken away from it, it retains the same fuel value regardless of the form in which it is used. "Chunk" wood, chips, hogged wood, sawdust or shavings of any given species all have the same calorific value at the same moisture content, although they will have very different burning characteristics.

Pellets of compressed wood will also have the same heating value per unit of weight, provided no binding agent is added in the pelletizing process. When binders are used, the fuel value of pelletized wood may be higher or lower than the woody constituent depending upon the calorific value, if any, of the binding material (wax, bitumen, starch, etc.). The advantages of pelletized wood lie chiefly in the fact that its greater

density reduces transportation and storage problems, the compression (or binder) may reduce the problem of dust in handling and the form lends itself to mechanical stoking. However, the act of pelletizing requires a significant energy input so that the net energy of the fuel is, in effect, reduced.

Charcoal

Charcoal is another form of wood fuel, but here certain constituents of the wood have been removed in the process (pyrolysis) of making the charcoal. Thus, although charcoal has a calorific value almost 50 percent higher than the same unit weight of wood from which it is made, the calorific value of the weight of charcoal produced is slightly less than half of the calorific value of the dry wood used to produce it. As a fuel, charcoal's principal advantage is that it burns without flame. Industrially it is very useful for the production of steel in certain countries which lack coal. Indeed, it has important roles to play in many specialized uses, but an extremely limited role in general applications as a fuel.

Wood Gas

Gas, often called "producer gas", is also a product of the pyrolysis of wood. It can be used for the operation of internal combustion engines and gas turbines. If the gas can be used close enough to the point of its production that it loses little of the heat at which it is generated, efficiency of use of 85 percent or better may be achieved. Techniques for making and using producer gas have existed for more than a century, but many technical problems still remain. However, the present energy crisis is spurring research and development in this field and the use of producer gas is likely to expand significantly, albeit in a limited sphere of usefulness.

A.4 The Relative Value of Wood as a Source of Energy

Wood, like most vegetable matter, consists essentially of carbon and hydrogen bonded together by biological action triggered by solar energy. In this form, the chemicals are in fact stored energy which can be released by combustion or can be converted into other forms of latent energy. Nevertheless, wood is not a particularly desirable fuel. It has a much lower fuel value per unit of weight than fossil fuels (i.e., it is bulky), it contains, when fresh, a great deal of moisture which is not easily removed, it is subject to decay -- and hence to loss of fuel value -- if improperly stored, and its rate of combustion is not easily controlled. On the other hand, it is widely distributed, it is almost free of sulphur and nitrogen, it can be produced and harvested after a fashion even by unskilled persons and, most importantly, it is a renewable resource.

But wood is also often called the most versatile solid known to man. No one has ever invented or developed a material with such a wide array of useful characteristics. Furthermore, wood can be processed into such forms as lumber, veneers, plywood, fibreboards, insulating boards, particleboards, flakeboards, and various combinations of these products with very little energy compared with that required for making steel, aluminum, metal alloys, plastics, cement and brick. To the extent that it is feasible to substitute wood for these other structural materials there will be a corresponding conservation of energy. It would therefore be prudent to assume that such substitutions will occur as the true costs of energy are translated into market prices for structural products and the logic of energy conservation ultimately filters through the economic system. In this connection, one should remember that many of the uses for which wood might be substituted for other materials were, in fact, filled by wood in the days of cheap energy (27).

The extent to which this substitution of materials could contribute to the conservation of energy is illustrated in the following table (Table A1.1) which is adapted from "Consistent Energy Accounting in the Production of Wood Products and Competing Materials" by Antoni Tenwolde and Robert N. Stone. (Paper presented at the "Resource Recovery and Conservation Symposium", 1978, quoting "Forest Products; an assured future" by E.A. Raynham. "Timber Trades Journal" 296 (5186) pp. 19-20).

It is also intriguing to note that when wood structural materials have served their prime purpose, they retain most, if not all, of their original fuel value. In contrast, most of the competing materials did not have any fuel value in the first place, but are merely energy sinks!

In a previous section, it was pointed out that the most efficient way to use wood in the production of gas or liquid fuels is to divert fossil fuels from furnaces for this purpose and replace them with wood fuel. Thus, we can now rank the possible uses of wood in the following descending order of usefulness in terms of energy conservation:

For fibre and structural products
For direct use "as is" for fuel
For the production of edible products
For the production of chemical products, such as methanol, ethanol, phenol and furfural.

TABLE A1.1

Relative Energy Consumption and Strength of Selected Materials

Material	Energy Input per unit of mass	Energy Input per Unit of Strength Tensile Strength	Modulus of Rigidity
Sawn softwood	1.0	1.00	1.00
Tempered hardboard	3.0	2.11	1.04
Reinforced concrete	4.6	8.06	1.10
Steel (EN-1)	32.0	27.89	3.26
Steel (EN-24)	32.0	8.70	3.26
Cast iron	32.0	16.28	6.68
Copper-zinc alloys	33.0	19.17	7.40
Plastic (polypropylene)	40.0	28.61	n.a.
Plastic (PVC rigid)	40.0	31.11	n.a.
Aluminum alloys	158.0	39.44	16.40
Titanium alloys	310.0	40.56	31.06
Magnesium alloys	230.0	57.17	22.34

In general, but particularly as between the first and second classifications in the above list, the higher the cost of energy, the greater the relative value of wood as fibre and structural material as compared to its value for other purposes when judged in terms of net energy consumption. As a corollary, the higher the cost of energy, the higher the relative economic value of wood for its best end-uses.

Rising costs of energy may be expected to have two somewhat conflicting pressures on the world wood supplies. First, it will tend to increase the demand for wood vis-à-vis competing structural materials in the developed countries; and, second, it will increase the demands for wood as fuel in third-world countries which cannot afford to import fossil fuels or atomic-energy systems.

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APPENDIX II

GLOSSARY OF TERMS

Appendix II (i)

GLOSSARY OF TERMS

Softwood Cover Type (S) - describes a forest condition whereby more than 75% of the volume is represented by softwood species.

Softwood-Hardwood Cover Type (SH) - describes a forest condition whereby 50-75% of the volume is represented by softwood species.

Hardwood-Softwood Cover Type (HS) - describes a forest condition whereby 50-75% of the volume is represented by hardwood species.

Hardwood Cover Type (H) - describes a forest condition whereby more than 75% of the volume is represented by hardwood species.

Volume Class - a description of a range of volumes per unit of area present within a forest type.

Tree Length Logging System - a method of harvesting forest products whereby the complete tree stem minus branches and top, is delivered to roadside.

Whole-Tree Logging System - a method of harvesting forest products whereby the complete tree, including branches and top, are delivered to roadside.

Short-Wood Logging System - a method of harvesting forest products whereby the tree stem minus branches and top is delivered to roadside in uniform pieces.

Full-Tree Logging System - same as whole-tree logging system.

Roundwood Equivalent - is the volume of logs or bolts needed to produce any given quantity of specified manufactured wood products.

Moisture Content (MC) - expresses the amount of water by weight found in the fuel. Commonly expressed in two categories - Dry Basis: Water as a percent of the oven-dry weight of wood, and Wet Basis: water as a percent of total wood sample weight.

Ash Content - expressed in percentage, represents the noncombustible residue in the fuel.

Calorific Value - a fuel's potential to release thermal energy; it is usually expressed in terms of "joules" or "British Thermal Units (Btu's)" per unit of mass or volume.

Fuel Value - see calorific value.

APPENDIX III

APPROPRIATE SI CONVERSIONS AND FUEL CHARACTERISTICS

Appendix III (i)

APPROPRIATE SI CONVERSIONS AND FUEL CHARACTERISTICS

A. Appropriate SI Conversions

1 acre	= 0.404685 ha (hectare)
1 cunit (100 ft^3 of solid timber)	= 2.831 m^3
1 mile	= 1.609344 km (exactly)
1 square foot	= 0.09290304 m^2 (exactly)
1 ton (2000 lb)	= 0.90718474 tonne (exactly)
1 lb/ft^3	= 16.02 kg/m^3
1 ha (hectare)	= 2.471054 acres
1 kg (kilogram)	= 2.2046226 pounds
1 km (kilometer)	= 0.6213712 mile
1 m (meter)	= 3.280840 feet
1 m^2 (sq meter)	= 10.76391 sq feet
1 m^3/ha	= 14.291 cu feet/acre
1 t (tonne)	= 1.1023112 tons
1 (litre)	= 0.2197 Imperial gallons
1 US gallon	= 3.785 liters (0.833 Imperial gallons)
1 boiler horsepower (hp)	= 33480 Btu's/hour
1 Btu	= 1.0551 kJ
1 kWhour	= 3 412 Btu's
1 kWhour	= 3 600 kJ
1 kWhour	= 859.845 kcal
1 kWhour	= 1.34 horsepower hours (hph)

B. Fuel Characteristics

- No 2 fuel oil heating value = 38 340 kJ/liter (165 000 Btu/Imperial gallon)
- No 6 Bunker C oil heating value = 41 830 kJ/liter (180 000 Btu/Imp gal)
- Minto Coal heating value = 26 741 kJ/kg (11 500 Btu/lb)
- Wood Pellets (12% MC) heating value = 17 393 kJ/kg (7 480 Btu/lb)
- Propane heating value = 26 161 kJ/L (112 724 Btu/Imp gal)
- Natural Gas heating value = 37 258 kJ/m^3 (1000 Btu/ft^3)
- Wood residue:

	Heating Value	Bulk Density
25% MC	15 810 kJ/kg (6 800 Btu/lb)	179.4 kg/m^3 (11.2 lb/ft^3)
40% MC	14 124 kJ/kg (6 075 Btu/lb)	201.9 kg/m^3 (12.6 lb/ft^3)
80% MC	10 985 kJ/kg (4 725 Btu/lb)	257.9 kg/m^3 (16.1 lb/ft^3)

APPENDIX IV

REGIONAL FUEL OPTIONS

APPENDIX 4.1.1

EXPLANATION OF FOREST TYPE CLASSIFICATION SYSTEM

Appendix 4.1.1 (i)

EXPLANATION OF FOREST TYPE CLASSIFICATION SYSTEM

During the period of 1974-1976 black and white aerial photographs were taken covering the Province of New Brunswick. These photographs were examined in stereo so that forest stands could be delineated. Each forest stand was labeled based on a classification system developed by the New Brunswick Department of Natural Resources. The main components of this classification system were:

1. Cover type
2. Height
3. Maturity
4. Volume
5. Species

The parameters associated with each of these elements of the classification are detailed in Table A4.1.1.

An example of the type of mapping produced using this classification system is shown in Figure A4.1.1. The stand highlighted in that figure is stand number 257. It has a softwood-hardwood cover type, and the trees composing the stand are uneven in height. The stand has an average volume of 140+ m^3 per hectare, and the trees within the stand have an average diameter of 26+ cm. The dominant species comprising the stand are balsam fir, spruce and tolerant hardwoods. The elements of this classification used to determine cut types were the cover-type and the volume-class.

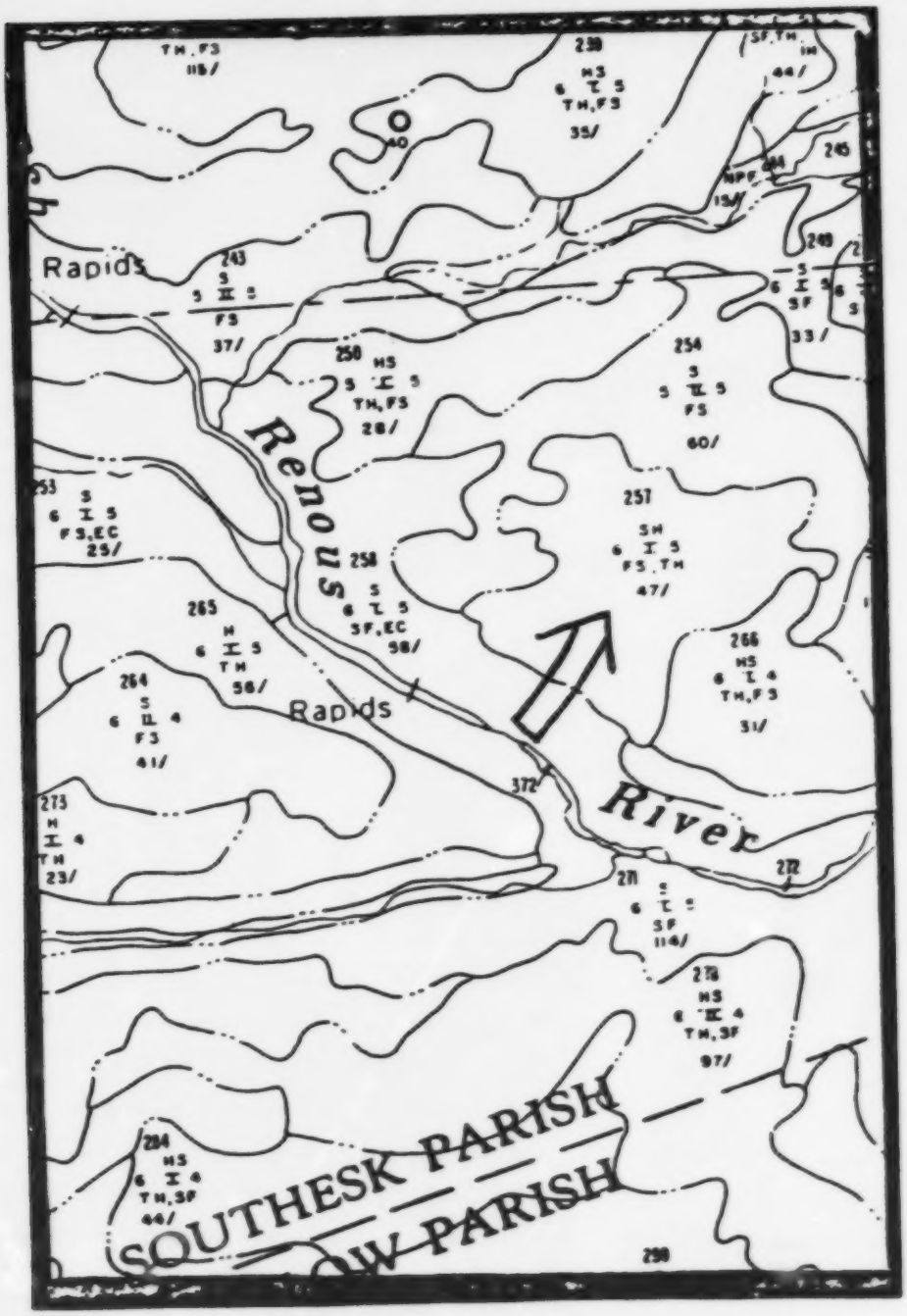

Figure A4.1.1 An Example of the Mapping Produced Using the Classification System

METRIC

COVER TYPE : S, SH, HS, H

HEIGHT CLASS : 1 0-4m, 2 5-8m, 3 9-12m
4 13-16m, 5 17m+, 6 uneven

MATURITY GROUP :

I 70+ m^3/ha ; 26cm + DBH class

II 35+ m^3/ha ; 16-24 cm DBH class

III 0-70 m^3/ha ; 26cm + DBH class

IV 0-70 m^3/ha, 10-14 cm + DBH class,
or no merchantable volume

VOLUME CLASS (m^3/ha) 1 0-35, 2 36-70,
3 71-105, 4 106-140, 5 140+

SPECIES ASSOCIATION

Table A4.1.1 Parameters Associated With Elements of the Classification

APPENDIX 4.1.2

DATA FROM SAMPLED CUTS

CUT NO.	TYPE	AREA	MC%	AV. PLOT WT. (KG)	TOTAL WEIGHT RESIDUE (OD TONN /HA)	RESIDUAL VOL (M3/HA)	RESIDUE WT (PART) (OD TONN /HA)	RESIDUE WT (TOTAL) (OD TONN /HA)
212-12	S15	19.00	28.20	14.40	35.64	0.00	0.00	0.00
193-14	S15	11.00	28.80	10.90	27.04	0.20	0.04	0.08
191-18	S15	23.00	33.30	30.10	71.91	4.85	0.58	1.62
190-21	S15	21.00	39.20	12.70	28.95	42.50	8.93	16.75
190-22	SH14	10.00	53.80	23.70	49.00	18.50	3.49	7.38
190-26	S15	61.00	42.20	26.90	60.14	13.42	2.69	5.28
190-28	S15	10.00	44.40	25.30	55.68	17.85	3.58	7.04
190-29	S15	86.00	38.60	22.60	51.86	19.05	3.85	7.49
190-17	S25	36.00	27.70	29.30	72.86	0.77	0.13	0.30
190-23	S15	252.00	34.20	40.10	95.14	8.91	1.66	3.57
300-8	S14	13.00	57.50	21.90	43.27	60.92	11.17	24.90
301-11	S15	127.00	24.90	9.10	23.23	30.52	5.37	13.66
261-12	S15	6.00	58.50	20.00	40.09	46.45	9.77	18.16
261-14	S15	16.00	29.40	20.20	49.64	40.07	8.17	15.68
262-5	SH23	22.00	26.50	11.00	27.68	14.34	2.72	8.01
262-8	S15	9.00	48.20	9.60	20.68	24.85	3.67	10.46
262-9	S15	77.00	49.60	18.40	39.14	11.84	2.67	7.00
280-11	SH24	26.00	16.80	18.10	49.32	17.45	3.69	10.16
280-35	S15	17.00	16.50	10.50	28.64	22.39	4.57	12.94
280-38	S15	14.00	26.40	14.90	37.54	12.50	2.44	6.80
263-39	H25	20.00	64.60	20.20	39.14	41.58	7.36	22.26
263-43	S15	55.00	40.50	18.30	41.36	16.88	3.46	9.46
285-2	S33	11.00	42.20	9.30	20.68	3.06	0.49	1.20
285-6	HS24	13.00	31.20	8.50	20.68	43.87	8.87	20.53
303-9	HS14	15.00	43.00	7.90	17.50	95.99	18.59	43.46
213-5	SH13	32.00	48.60	33.00	70.64	1.79	0.36	0.81
229-22	SH25	21.00	26.80	25.90	64.91	1.15	0.28	0.63
212-9	S14	27.00	31.20	11.90	28.95	0.00	0.00	0.00
193-1	S24	15.00	22.80	9.70	25.14	0.68	0.14	0.27
193-11	S13	8.00	21.70	13.90	36.27	0.00	0.00	0.00
193-10	S14	20.00	1.60	16.70	45.50	0.00	0.00	0.00
263-42	HS15	8.00	14.60	13.50	37.54	41.90	9.26	24.65
287-4	S32	12.00	45.00	1.50	25.14	0.00	0.00	0.00

CUT NO.	TYPE	AREA	MC%	AV. PLOT WT. (KG)	TOTAL WEIGHT RESIDUE (OD TONN /HA)	RESIDUAL VOL (M3/HA)	RESIDUE WT (PART) (OD TONN /HA)	RESIDUE WT (TOTAL) (OD TONN /HA)
361-36	H23	9.00	53.50	11.80	24.50	1.07	0.26	0.65
361-18	H35	50.00	57.40	5.30	10.82	0.00	0.00	0.00
282-1	H24	8.00	19.40	1.10	29.60	7.18	2.16	4.67
280-36	SH15	6.00	25.80	17.30	43.91	49.64	12.34	30.22
280-37	HS15	37.00	13.20	15.40	43.27	31.72	7.32	18.81
261-X	S14	52.00	33.70	14.80	35.32	31.53	6.51	12.25
280-39	SH15	14.00	14.70	9.40	26.10	24.33	5.10	11.85
280-18	HS25	30.00	13.10	0.90	25.14	24.91	5.74	14.82
358-14	S14	22.00	13.80	6.30	17.50	7.75	1.45	3.70
358-11	H15	10.00	50.90	10.90	22.91	2.33	0.43	1.32
395-38	S34	20.00	38.20	9.30	21.32	5.96	1.11	3.29
395-9	SH32	16.00	26.60	7.50	18.77	2.36	0.37	0.83
393-7	S23	36.00	17.90	8.50	22.91	0.00	0.00	0.00
393-23	HS33	21.00	19.80	0.10	18.77	8.82	1.72	5.06
393-24	SH33	50.00	25.60	6.10	15.59	28.49	4.62	13.12
413-1	SH34	9.00	19.60	4.40	11.77	25.89	3.64	10.66
334-2	S35	55.00	23.00	17.60	45.50	5.99	1.08	3.29
226-2	S24	10.00	3.50	6.40	15.27	0.00	0.00	0.00
262-13	SH15	68.00	17.50	13.70	37.23	12.03	2.35	6.90
318-1	S25	17.00	13.90	10.90	30.54	0.00	0.00	0.00
318-8	S25	16.00	18.60	13.30	35.64	9.31	1.58	4.42
319-5	SH35	13.00	12.80	9.80	27.68	2.02	0.30	0.88
335-1	HS35	12.00	53.00	14.50	30.23	42.83	11.81	27.21
374-5	HS34	17.00	39.60	17.00	38.82	15.24	2.36	6.84
356-12	S15	30.00	21.30	6.60	17.18	71.25	11.90	33.73
356-7	HS23	17.00	40.00	10.20	22.91	49.37	8.84	26.64
377-16	SH14	10.00	51.80	7.40	15.60	56.52	9.13	25.78
377-17	SH15	7.00	7.00	10.90	29.60	45.23	8.06	24.75
358-15	S13	16.00	25.20	6.70	17.18	1.07	0.20	0.61
301-12	SH15	21.00	53.60	21.90	45.50	49.19	9.32	24.35
301-13	HS15	15.00	70.10	13.90	26.10	53.52	8.57	24.54
360-20B	S24	40.00	26.20	14.80	37.23	3.81	0.67	1.96
360-20A	S25	30.00	34.10	15.40	36.59	0.76	0.14	0.43
360-19B	S23	4.00	21.30	9.90	26.09	2.96	0.54	1.60

COT NO.	TYPE	AREA	MC%	AV. PLOT WT. (KG)	TOTAL WEIGHT RESIDUE (OD TONN /HA)	RESIDUAL VOL (MJ/HA)	RESIDUE WT (PART) (OD TONN /HA)	RESIDUE WT (TOTAL) (OD TONN /HA)
360-19A	S22	3.00	27.20	12.00	29.91	0.00	0.00	0.00
356-8	S23	33.00	43.20	17.10	37.86	18.21	2.91	8.24
395-55	S22	12.00	30.10	2.50	6.04	1.26	0.22	0.61
395-59	S22	10.00	30.00	5.60	13.68	2.39	0.38	1.29
317-9	S24	19.00	33.60	20.10	47.73	11.78	0.00	0.00
264-1	S15	18.00	51.80	17.50	36.59	64.77	8.97	24.12
189-2	S15	73.00	30.90	23.10	56.00	0.00	0.00	0.00
246-1	S35	11.00	36.20	24.40	56.95	19.66	3.48	9.18
303-3	S35	37.00	34.30	8.90	21.00	8.25	1.26	3.73
318-4	S25	8.00	45.20	18.30	40.09	17.30	2.31	6.40
191-10A	S25	31.00	80.60	28.10	49.64	0.00	0.00	0.00
191-10B	S25	31.00	17.40	21.60	58.54	0.00	0.00	0.00
191-10C	S25	32.00	56.60	23.80	48.36	0.00	0.00	0.00

Appendix 4.2.1 (iii)

APPENDIX 4.1.3

PHOTOGRAPHS OF
TYPICAL CUTOVERS AREAS
AND HARVESTING MACHINERY

FIGURE A4.1.2 A typical cut with residuals remaining.

FIGURE A4.1.3 Few residuals remain on this two year old cut that originated from a five vol. class.

FIGURE A4.1.4 The result of two years after harvest of a softwood cut that originated from a two volume class.

FIGURE A4.1.5 The result two years after harvest of a softwood cut that originated from a four volume class.

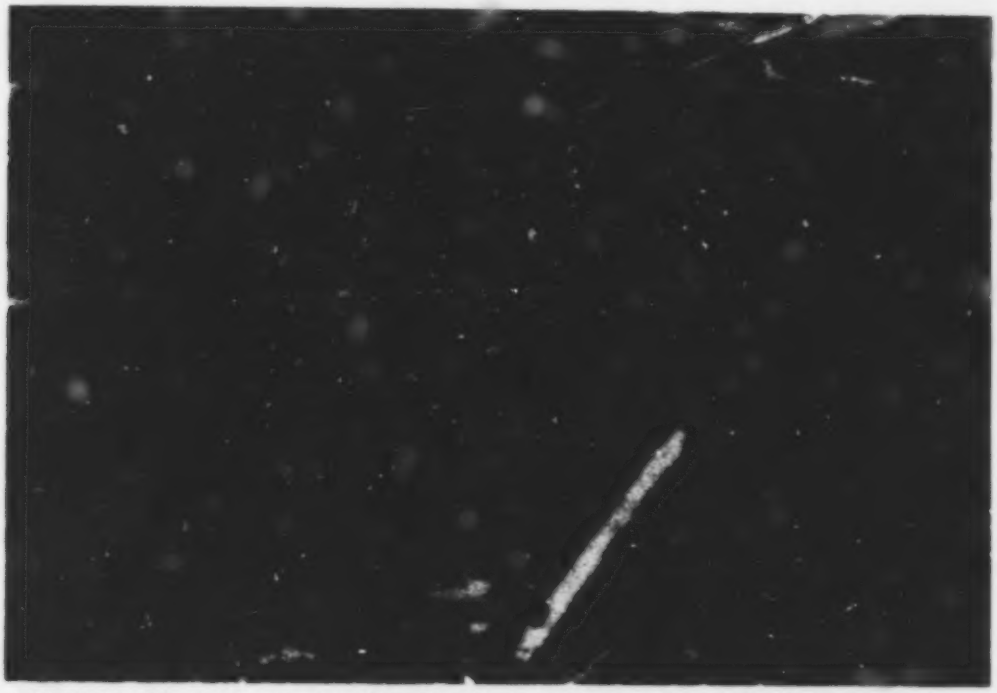

FIGURE A4.1.6 A typical plot after the slash has been removed and weighed.

FIGURE A4.1.7 Slash on the plots was severed from the surrounding material by using a chain saw.

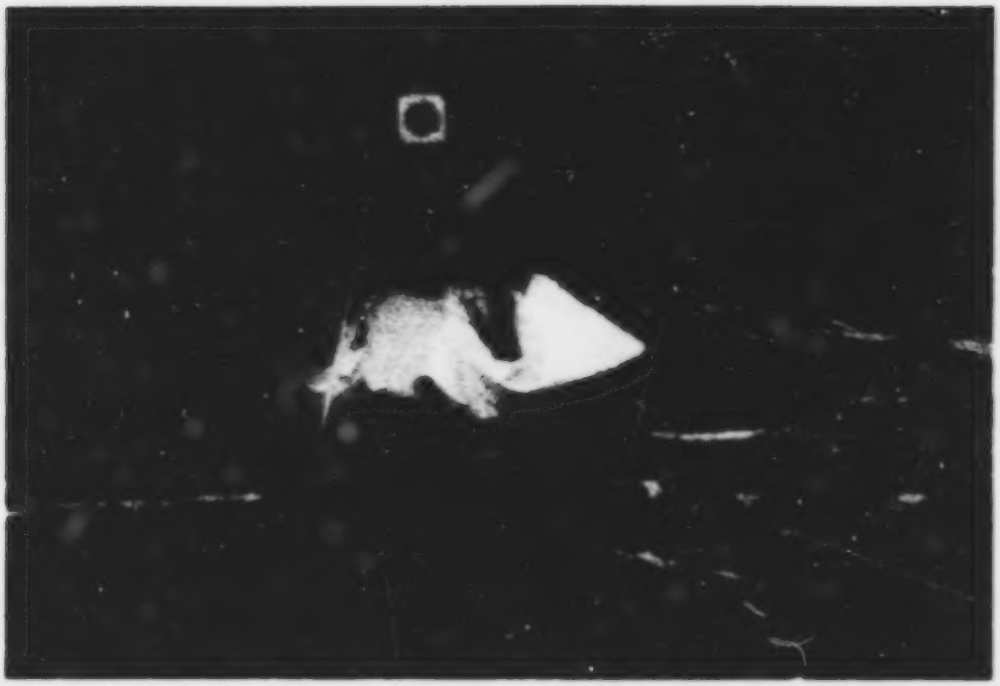

FIGURE A4.1.8 Slash removed from the plot was loaded onto a tarpaulin and raised for weighing.

FIGURE A4.1.9 Material transported in contact with the ground can accumulate mud and stones that can greatly affect chipping efficiency.

FIGURE A4.1.10 Material transported to roadside clear of the ground does not accumulate unwanted material and thus makes chipping more efficient.

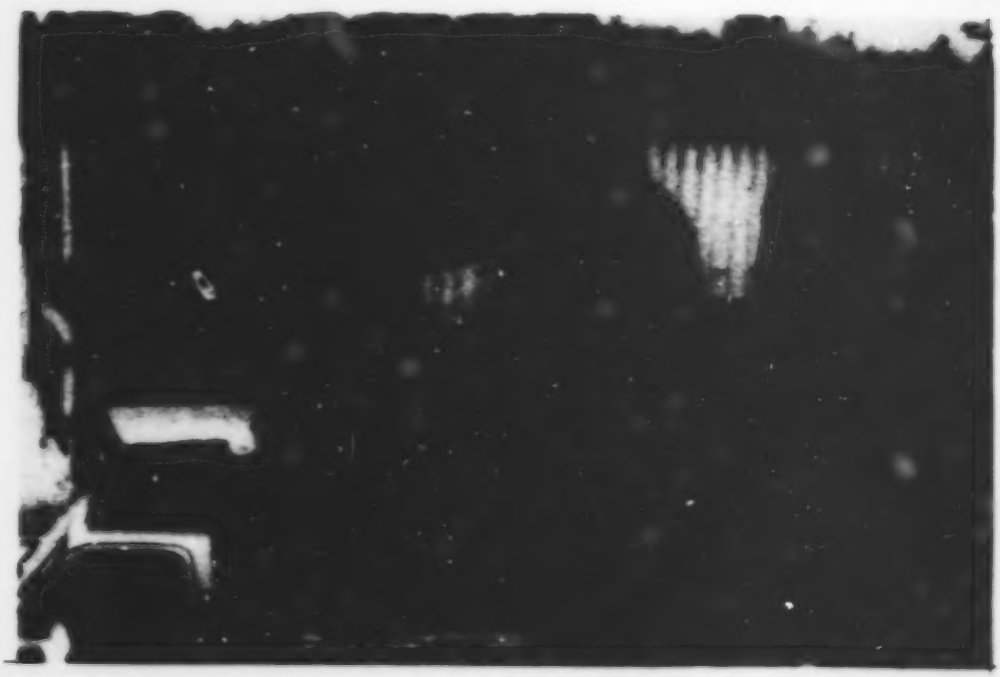

FIGURE A4.1.11 A side view of the Bruks chipping system. The grapple on the forwarder feeds slash into the chipper and the chips are blown into the bin at the rear. When full, the forwarder travels to roadside and dumps the bin into waiting vans.

APPENDIX 4.2.1

LIST OF OIL CONSUMERS
IN REGION 2

SCHOOLS

HOSPITALS

SMALL INDUSTRIES

LARGE INDUSTRIES

Appendix 4.2.1 (i)

OIL FUEL CONSUMPTION - FOREST REGION 2

1. Schools

DISTRICT	LOCATION	OIL CONSUMPTION 1982/1983(L)		DISTANCE FROM FOREST REGION
		#2 OIL	#6 OIL	#2 CENTRE (km)
6	La Riviére, Pokemouche	34 408		90
6	Gilbert Finn, Inkerman	25 907		91
6	Elémentaire, Le Goulet	35 409		98
6	Elémentaire, Shippagan	45 317		104
6*	Intermédiare, Shippagan	109 318		110
6	Elémentaire, Lamèque	62 052		110
6	Elémentaire, Petite Rivière	53 654		117
6	Elémentaire, Miscou Centre	9 373		127
6	Ecole Marie Esther	2 205	105 642	111
	TOTAL	377 643	105 642	

Appendix 4.2.1 (ii)

OIL FUEL CONSUMPTION - FOREST REGION 2

1. Schools

DISTRICT	LOCATION	OIL CONSUMPTION 1982/1983(L)		DISTANCE FROM FOREST REGION
		#2 OIL	#6 OIL	#2 CENTRE (km)
7	Ste-Rose	22 913		55
7	St-Isodore Centrale	34 925		50
7	St-Isodore, Elémentaire	7 983		50
7	St-Pierre	Electric	Heat	53
7	Pont Landry	19 116		55
7	La Ruche, Tracadie	65 878		55
7	Le Tremplin, Tracadie	NA		55
7	Polyvalente, W.A. Losier	NA		53
7	La Source, Sheila	NA		53
7	Haut Sheila	14 986		53
7	La Ville des Amis	NA		53
7	Rivière-du-Portage	32 990		45
7	Légére	22 890		55
7	Point Grave	18 906		53
7	Brantville	22 725		53
7	Point La France	21 987		53
7	Néguac, Elémentaire	67 837		30
7	La Rencontre, Néguac	NA		44
7	Lagacéville	22 981		34
	TOTAL	376 117		

Appendix 4.2.1 (iii)

OIL FUEL CONSUMPTION - FOREST REGION 2

1. Schools

DISTRICT	LOCATION	OIL CONSUMPTION 1982/1983(L)		DISTANCE FROM FOREST REGION
		#2 OIL	#6 OIL	#2 CENTRE (km)
8	Blackville Elementary	Electric Heat		42
8	Quarryville Elementary	9 421		30
8	Millerton Jr. High	34 025		17
8	Lower Derby Elementary	12 557		13
8	Millerton Elementary	8 018		17
8	Boom Road Elementary	6 171		23
8	Red Bank Elementary	5 710		26
8	Sunny Corner Elementary	8 244		25
8	Sillikers Elementary	8 020		30
8	Sunny Corner	Electric Heat		25
8*	N & S Esk Regional High	95 234		18
8	Newcastle Croft Elementary	Electric Heat		25
8*	Harkins Complex	285 714		
8	Miramichi Valley High	Electric Heat		6
8	Gretna Green Elementary Douglastown	Elec. Heat Pump		3
8	Tabusintac Jr. High	5 025		50
8	Tabusintac Elementary	9 559		50
	TOTAL	487 698		

Appendix 4.2.1 (iv)

OIL FUEL CONSUMPTION - FOREST REGION 2

1. Schools

DISTRICT	LOCATION	OIL CONSUMPTION 1982/1983(L)		DISTANCE FROM FOREST REGION
		#2 OIL	#6 OIL	#2 CENTRE (km)
9	Doaktown Primary	21 554		75
9	Doaktown Elementary	41 909		75
9	Doaktown High	36 335		75
9	Upper Miramichi Regional High	79 646		50
9	Upper Miramichi Elementary	40 934		50
9*	Stanley High	101 036		110
9	Stanley Elementary	20 904		110
	TOTAL	342 318		

Appendix 4.2.1 (v)

OIL FUEL CONSUMPTION - FOREST REGION 2

1. Schools

DISTRICT	LOCATION	OIL CONSUMPTION 1982/1983(L)		DISTANCE FROM FOREST REGION
		#2 OIL	#6 OIL	#2 CENTRE (km)
10	Nelson Jr. High	60 365		6
10	Chatham Head Primary	11 235		0
10*	Chatham Jr. High	188 911		0
10*	St. Michael's Elementary	108 635		0
10	St. Andrew's Elementary	48 907		0
10	Chatham Head Elementary	43 836		0
10	Napan Elementary	25 848		10
10	Loggieville Elementary	13 028		10
10	Miramichi Elementary	16 328		6
	TOTAL	517 093		

Appendix 4.2.1 (vi)

OIL FUEL CONSUMPTION - FOREST REGION 2

1. Schools

DISTRICT	LOCATION	OIL CONSUMPTION 1982/1983(L)		DISTANCE FROM FOREST REGION #2 CENTRE (km)
		#2 OIL	#6 OIL	
39	Acadieville Elementary	24 902		38
39	Aldouane	16 149		58
39	Pointe Sapin	25 730		46
39*	Richibucto Jr. High	102 153		60
39	Richibucto Village Elementary	22 420		60
39	Rogersville Assumption Secondary	31 849		33
39	St. Charles	18 932		55
39	St. Louis Elementary	80 001		52
39	Baie Ste. Anne Regional	Electric Heat		43
39	W.F. Boivin	Electric Heat		33
39	Monseigneur M.F. Richard High, St. Louis	Electric Heat		52
	TOTAL	322 136		

Appendix 4.2.1 (vii)

OIL FUEL CONSUMPTION - FOREST REGION 2

Total For All Schools

	#2 Oil Litres	#6 Oil Litres
District #6	377 643	105 642
#7	376 117	
#8	487 698	
#9	342 318	
#10	517 093	
#39	322 136	
Total Litres	2 423 005	105 642
Total Imp. Gallons	532 997	23 240
Total for Small Schools		
Litres	1 432 004	--
Imp. Gallons	315 003	--
Total for Large Schools		
Litres	991 001	105 642
Imp. Gallons	217 994	23 240

Appendix 4.2.1 (viii)

OIL FUEL CONSUMPTION - FOREST REGION 2

2. Hospitals

HOSPITAL	LOCATION	OIL CONSUMPTION LITRES 1982		DISTANCE FROM FOREST REGION #2 CENTRE (km)
		#2 OIL	#6 OIL	
Chaleur	Bathurst		2 510 000	70
Hôtel Dieu	Chatham		1 244 000	10
Hôtel Dieu	Tracadie		687 000	72
Hôpital L'Enfant de Jésus	Caraquet		299 462	100
TOTAL HOSPITALS	Litres		4 740 462	
	Imp. Gallons		1 042 776	

Appendix 4.2.1 (ix)

OIL FUEL CONSUMPTION - FOREST REGION 2

3. Small Industrial

FISH PLANTS

COMPANY NAME	LOCATION	NUMBER OF EMPLOYEES	TYPE OF PLANT	ENERGY CONSUMPTION	
				#2 oil Gallons	#6 oil Gallons
1. Acadie Marée et Froid Ltée	Shippegan Gloucester County	10 - 30	Salmon Squid Snails		
* 2. Albert & Sons Fisheries Ltd	Néguac Northumberland County	40 - 75	Herring Fillets		
3. Association Co-operative des Pecheurs de L'île Ltée	Lameque Gloucester County	20 - 725	Cod Fillets Flounder Shrimps Herring		
4. Baie Chaleur Packers Ltd	Bas-Caraquet Gloucester	70 - 175	Herring Crab Meat	Fuel consumption developed as totals only from known consumption of 11 plants contained in this list.	
5. Baie des Chaleur Cold Storage Ltd	Caraquet Gloucester County	10 - 150	Mackerel Herring Gaspereau		
6. Baie Ste Anne Co-Op Ltd.	Baie Ste Anne, Northumberland County	2 - 105	Cod Fillets Flounder Smelt, Cod Oysters		
* 7. Blue Cove Packing Co. Ltd.	Anse Bleue Gloucester County	40 - 45	Herring Mackerel		
8. Bluenose Fisheries Ltd. (Cocagne Division)	Cocagne Kent County	60 - 400	Lobster Meat Crab Meat Scallops Salmon		
9. Buctouche Fish Market Ltd.	Buctouche Kent County	7 - 30	Smelt, Cod Mackerel Scallops Crab Meat		
10. Brunswick Fish Market Co. Ltd.	Val Comeau Gloucester County	10 - 20	Clams, Cod Mackerel Lobster Meat Eel		

OIL FUEL CONSUMPTION - FOREST REGION 2

3. Small Industrial

FISH PLANTS

	COMPANY NAME	LOCATION	NUMBER OF EMPLOYEES	TYPE OF PLANT	ENERGY CONSUMPTION	
					#2 oil Gallons	#6 oil Gallons
11.	Carapec Ltée	Caraquet Gloucester County	20 - 30	Flounder Shrimps, Cod Fillets		
*12.	Connors Bros. Ltd. (Caraquet Division)	Bas-Caraquet Gloucester County	3 - 40	Herring Pickled		
13. *	Connors Bros. Ltd. Crab Plant	Shippegan Gloucester County	200 - 800	Lobster Meat Crab Meat Smelt Scallops		
14.	Connors Bros. Ltd. (Shippegan Division)	Shippegan Gloucester County	15 - 350	Crab Meat Groundfish Herring Kippers		
15.	Gauthier, L.L. & Sons Co. Ltd.	Shippegan Gloucester County	30 - 150	Cod, Smelt Herring Mackerel Lobster	Fuel consumption developed as totals only from known consumption of 11 plants contained in this list.	
16.	Gulf Seafood Co. Ltd.	Sheila Gloucester County	40 - 100	Cod Liver Oil, Chicken Haddie, Lobster		
17. *	Gully Fish & Food Products Co. Ltd.	Shippegan Gloucester County	6 - 550	Crab Meat Frozen		
18.	Kent Fish Products	Buctouche Kent County	10 - 350	Herring Gaspereau		
19. *	Maisonnette Seafoods Ltd.	Anse-Bleue Gloucester County	40 - 45	Herring Marinated Pickled, Roe		
20.	McGraw Fresh & Frozen Fish	Tracadie Gloucester County	5 - 22	Cod, Clams Eel, Herring Mackerel Scallops Smelt		

Appendix 4.2.1 (xi)

OIL FUEL CONSUMPTION - FOREST REGION 2

3. Small Industrial

FISH PLANTS

	COMPANY NAME	LOCATION	NUMBER OF EMPLOYEES	TYPE OF PLANT	ENERGY CONSUMPTION	
					#2 oil Gallons	#6 oil Gallons
* 21.	Mills Seafood Ltd.	Buctouche Kent County	3 - 100	Clams Frozen		
22.	National Sea Products Ltd. (Shippegan Division)	Shippegan Gloucester County	15 - 530	Herring Cod, Sole Fillets Crab Meat Shrimp		
23.	Néguac Shell-fish Co. Ltd.	Lower Néguac Northumber-land County	10 - 174	Gaspereau Clams, Cod Mackerel Lobster		
24.	Pêcheries Alfo Ltée	Petit-Rocher Gloucester County	150 - 200	Mackerel Lobster Meat Herring	Fuel consumption developed as totals only from known consumption of 11 plants contained in this list.	
25.	Pêcheries Caraquet Ltée	Caraquet Gloucester County	1 - 45	Herring Marinated		
26.	Pêcheries St-Paul Ltée	Bas-Caraquet Gloucester County	40 - 70	Cod Herring Mackerel		
27.	Pêcheries Roma Ltée - Roma Fisheries Ltd.	Grande-Anse Gloucester County	1 - 50	Herring Fillets Marinated		
* 28.	Poissonnerie R & G, Cormier Ltée	Maisonnette Gloucester County	15 - 27	Herring Lobster Crab, Squid		
29.	Produits Belle Baie Ltée	Caraquet Gloucester County	22 - 267	Crab Meat Shrim, Cod Sole Fillets		
30.	Produits Des Pêches M.O. Duguay Ltée	Lamèque Gloucester County	5 - 60	Cod Herring Mackerel		

Appendix 4.2.1 (xii)

OIL FUEL CONSUMPTION - FOREST REGION 2

3. Small Industrial

FISH PLANTS

	COMPANY NAME	LOCATION	NUMBER OF EMPLOYEES	TYPE OF PLANT	ENERGY CONSUMPTION #2 oil Gallons	ENERGY CONSUMPTION #6 oil Gallons
31.	Produits Du Gulf St. Laurent Ltée	Caraquet Gloucester County	14 - 20	Meal, Fish (Feed) Fish Oil		
32.	Richard B.A. Ltd.	Sainte-Anne-de-Kent Kent County	40 - 90	Lobster Meat Chicken Haddie Crab Meat		
* 33.	Richibucto Village Fisherman's Co-Op	Richibucto Village Kent County	75 - 90	Cod Flounder Gaspereau Crab Lobster		
* 34.	United Maritime Fisherman Co-Op	Richibucto Village Kent County	20 - 260	Lobster Crab, Smelt Scallops Eel		
Total for Fish Plants (Imperial gallons)				**	548 000	1 932 000
				Litres	2 491 208	8 782 872

* Denotes plant which was part of energy audit sample.

**Data was obtained from the agency conducting "energy audits" of the total fuel consumed for 11 plants, and an extrapolation has been made from this to develop totals of each fuel for the 34 plants. The plants in which "energy audits" have been made are identified with an asterisk.

Appendix 4.2.1 (xiii)

OIL FUEL CONSUMPTION - FOREST REGION 2

4. Large Industrial Consumers

	#2 Oil (litres)	#6 Oil (litres)
BM & S Mines - Bathurst		66 280 000
Heath Steele	(Not in Operation)	
Boise Cascade - Newcastle		20 000 000 (estimated)
Acadia Forest - South Nelson		26 000 000 (estimated)
Consolidated Bathurst - Bathurst		61 825 000
Grand Total Large Industrial:		= 174 105 000 litres
		= 38 298 500 Imp. gallons

Appendix 4.2.1 (xiv)

OIL FUEL CONSUMPTION - FOREST REGION 2

Grand Totals

		#2 Oil (litres)	#6 Oil (litres)
1. Schools	(Small)	1 432 004	
	(Large)	991 001	105 650
2. Hospitals			4 740 462
3. Small Industry		2 491 208	8 782 872
4. Large Industry		(Not available, but small)	174 105 000
TOTAL Litres		4 914 213	187 733 984
TOTAL Imp. Gallons		1 080 970	41 296 520

APPENDIX 4.2.2

CAPITAL COST ESTIMATES

Appendix 4.2.2 (i)

SMALL SCHOOL

Capital Cost Estimate

1 - wood-fired boiler of 146 kW (500,000 Btu's) hot water complete with stoker feeder installed (assumes space available in school)	$15 000
2 - connections to existing system (piping and electrical)	1 200
3 - wood-receiving hopper (assumes manual reclaim to screw conveyor)	26 000
4 - engineering and contingency	7 800
	$50 000

Appendix 4.2.2 (ii)

LARGE SCHOOL

Capital Cost Estimate

1 - site works	$ 20 000
2 - wood-receiving bin complete with roof and space for hot water boiler and auxiliaries	90 000
3 - one hot water boiler complete with auxiliaries	60 000
4 - piping and electrical connections into existing systems	8 000
5 - engineering and contingency	25 000
	$203 000

Appendix 4.2.2 (iii)

Institutional Wood-Fired Boiler

Capital Cost Estimate

1 - site works - prepare site for new boiler, receiving hopper and silos allowance for road access	$ 30 000
Allowance for building modifications	30 000
Subtotal	60 000
2 - allowance for 1 silo of 6M x 10.5 M high (20' by 35' high) - erected	85 000
3 - machinery - receiving hopper - including bottom withdrawal, screw conveyor, bucket elevator installed, silo withdrawal (included above)	59 000
chain conveyor (on top of silo) (installed)	8 500
chain conveyor (under silo) 25' installed	16 000
infeed to boiler - installed	15 000
Allowance for electrical connections	7 000
Subtotal	$105 500
4 - boiler - 1 wood-fired boiler of 966 kw (100 hp) capacity complete with auxiliaries	130 000
+ erection	15 000
+ electrical	4 000
Subtotal	$149 000
5 - allowance for piping assume 125 psig piping + water makeup + instrument air + blowdown and drains (this assumes that the boiler is being added to an existing system)	6 000
6 - electrical - feeds + controls	12 000
7 - allowance for taxes at 18 percent on $200 000	36 000
8 - interest during construction 10 percent on on $200 000 for six months	10 000
9 - Engineering + contingency @ 25 percent of $400 000	100 000
TOTAL	$563 500

SMALL INDUSTRY

Capital Cost

The boiler size is 966 kW (approximately 100 hp), and the costs for the boiler, its auxiliaries, the civil works, taxes, plus engineering and contingency are assumed to be the same as for the institutional system (hospital).

Appendix 4.2.2 (v)

Large Industrial Wood-Fired Boiler

Capital Cost Estimate

1 - site works - prepare site for new boiler, receiving hopper and new silos (2) work on access road to site Allow			$ 300 000
2 - allowance for 3 silos - each 9m x 15 m high (30' x 50' high) @ $80 000 each erected			240 000
3 - allowance for conveyors			
- receiving hopper - live bottom, screw	80 000		
- bucket elevator	45 000		
- chain conveyors on bin (3)	40 000		
- silo withdrawal systems	12 000		
- feed to boiler	35 000		
	212 000		
allow for installation	60 000		
	272 000		272 000
4 - allowance for miscellaneous wood handling			
- truck scales installed	68 000		
- moisture detector installed	15 000		
- conveyor scales	12 000		
- compressor +	15 000		
	110 000		110 000
5 - allowance for ash handling			72 000
6 - wood-fired boiler - 50 000 pph @ 300 psig complete with auxiliaries + erection			1 450 000
7 - instrumentation complete with installation			110 000
8 - piping and valving			60 000
9 - electrical			115 000
10 - building for new boiler - 15m high x 12m x 12m - (50' high x 40' x 40') = 1600 ft^2 @ $125			200 000
+ enclosure around bins			80 000
11 - allowance for taxes @ 18 percent of equipment (excluding boiler) (18% of 1,260,000)			226 000
Subtotal			$3 235 000
12 - engineering including design, field work, design - 194 000 field - 45 000			239 000
13 - contingency allowance @ 15 percent			521 000
14 - interest during construction @ 15 percent for half capital cost over 10 months			250 000
TOTAL			$4 245 000

APPENDIX 4.2.3

DEVELOPMENT OF COSTS FOR WOOD FUEL AT VARIOUS CLASSES OF CONSUMERS

Appendix 4.2.3 (i)

DEVELOPMENT OF COSTS FOR WOOD FUEL AT VARIOUS CLASSES OF CONSUMERS

Small Schools

See Section 4.4 for relevant details.

The cost development assumes that for government-owned institutions, the return on investment is such as to return the capital cost over a period of 10 years.

Ratio of $\frac{\text{Net Savings}}{\text{Investment}} = 0.10$

- the investment (capital cost)	=	$50 000
- allowance for extra expenses	=	$ 2 000
- oil fuel savings 51 000 litres (11 230 Imp. Gallons of #2 oil @ $0.297 litre ($1.35 Imp. gallon)	=	$15 147
- wood fuel -		
203 tonnes (224 tons) @ 80 percent MC (dry basis)		
160 tonnes (176 tons) @ 40 percent MC		
143 tonnes (158 tons) @ 25 percent MC		
Wood fuel allowance	=	$ 8 147
Net savings	=	$ 5 000

Wood fuel cost at the school to be competitive with #2 oil = $40.13/tonne ($36.41/ton) @ 80 percent MC
$50.92/tonne ($46.20/ton) @ 40 percent MC
$56.97 tonne ($51.69/ton) @ 25 percent MC

DEVELOPMENT OF COSTS FOR WOOD FUEL AT VARIOUS CLASSES OF CONSUMERS

Large Schools

See Section 4.4 for relevant details.

The cost development assumes that for government-owned institutions, the return on investment is such as to return the capital cost over a period of 10 years.

$$\text{Ratio of } \frac{\text{Net Savings}}{\text{Investment}} = 0.10$$

$$0.10 = \frac{\text{Oil fuel savings - wood fuel - extra expenses}}{\text{Investment}}$$

- the investment (capital cost) = $203 000
- allowance for extra expenses = $ 5 000
- oil fuel savings 100 000 litres per year (21,997 imp gallons) @ 1.35/imperial gal = $ 29 700
- wood fuel - (approximate)
  403 tonnes (445 tons) @ 80 percent MC (dry basis)
  313 tonnes (345 tons) @ 40 percent MC (dry basis)
  280 tonnes (309 tons) @ 25 percent MC (dry basis)

Wood fuel allowance = $ 4 500

Net Savings = $ 20 300

Wood fuel cost at the school to be competitive
= $11.17/tonne (10.13/ton) @ 80 percent MC
$14.38/tonne (13.05/ton) @ 40 percent MC
$16.08/tonne (14.59/ton) @ 25 percent MC

Appendix 4.2.3 (iii)

Institutional Load (Hospital)

A study was done of a typical institutional load such as a hospital/care home.

Consider the following as parameters for the typical installation:

- present oil consumption of 900 000 litres (197,976 Imp. Gallons) per year at an efficiency of 75 percent, equal to 28.2 x 10^9 KJ (26.7 x 10^9 Btu's) output.

- Bunker C oil of 41 830 kJ/litre (180 000 Btu's/ Imp. Gallon), conversion efficiency of 75 percent, cost of $0.22/litre ($1/Imp. Gallon).

- wood fuel available at moisture contents of 80 percent Dry Basis, 40 percent, 25 percent. The conversion efficiency is 65 percent. (The efficiency may well rise for dry fuel of 40 percent or 25 percent MC, but the 65 percent represents a realistic average.)

- assume wood-fired units of 966 kW (approximately 100 hp) operating in the base load mode at a load factor of 75 percent, equal to 22.8 x 10^9 KJ (21.7 x 10^9 Btu's) per year.

- capital cost for the boiler plus auxiliaries, estimated to be $563 500; assume a grant of 15 percent, (net cost $478 975.00).
- allow for payback of eight years.
- maintenance and servicing costs increased by $15 000/year.
- insurance costs on new assets @ $5 000.

Summary

Boiler capacity 966 kW

Capital cost = $478 975 (after grant)

Heat supplied from wood = 22.8 x 10^9 kJ (21.7 x 10^9) Btu's per year

Wood consumption @ 80 percent MC = 3193 tonnes (3518 tons)
@ 40 percent MC = 2483 tonnes (2736 tons)
@ 25 percent MC = 2219 tonnes (2448 tons)

Oil displaced = 726 751 litres (159,866 Imp. gallons)
= $159 885

Allowance for wood cost developed as follows:

$$\text{Ratio of } \frac{\text{Net Savings}}{\text{Investment}} = 0.125$$

$$0.125 = \left(\frac{\text{Oil fuel savings - Wood fuel Cost - Extra Expense}}{\text{Investment}}\right)$$

$$0.125 = \left(\frac{159\,885 - X - 20{,}000}{478\,975}\right)$$

Wood fuel allowance = $80 013

Allowance/unit @ 80 percent MC = $25.06/tonne ($22.74/ton)
@ 40 percent MC = $32.22/tonne ($29.24/ton)
@ 25 percent MC = $36.06/tonne ($32.72/ton)

Savings per year = $59 871.00

Small Industrial Load (Fish Plant)

Consider the following as parameters for the typical installation.

- the present oil consumption is in the order of 587 000 litres (129,124 Imp. Gallons) per year at an efficiency of 75 percent, equal to 18.4 x 10^9 kJ (17.4 x 10^9 Btu's) output.

- the present fuel is Bunker C having a heat content of 41 830 kJ/litre (180 000 Btu's per Imp. gallon) at a cost of 22¢/litre ($1.00/Imp. gallon).

- wood fuel is available at moisture contents of 80 percent Dry Basis, 40 percent Dry Basis, and 25 percent Dry Basis.

- conversion efficiency for wood fuel is assumed to be 65 percent (considered a realistic average for the relatively small boiler).

- assume the wood-fired boiler of 966 kW (100 hp) operating in the base-load mode producing 7.8 x 10^9 kJ (7.4 x 10^9 Btu's) per year.

This equates with 248 625 litres (54 691 Imp. gallons).

- the wood consumption:
  @ 80% MC (44.5% wet basis) = 1092 tonnes (1203 tons)
  @ 40% MC (28.5% wet basis) = 849 tonnes (936 tons)
  @ 25% MC (20.0% wet basis) = 759 tonnes (836 tons)

- the capital cost for the boiler, complete with auxiliaries, is estimated to be $563 500; assuming a grant of 15 percent, the net cost would be $478 975.

- allowance for payback - 4 years.

- maintenance and servicing costs increased by $12 000 per year.

- the operating staff would be increased by one man for wood-handling (estimated cost is $15 000 per year of 6 to 8 months)

- insurance costs would amount to $7 200.00 per year.

Allowance for wood cost developed as follows:

$$\text{Ratio of } \frac{\text{Net Savings}}{\text{Investment}} = 0.25$$

Net savings = oil savings - wood fuel costs - extra expenses
= $119 743.

Since oil savings only amount to $54 697, it is evident that the wood-fired boiler, based on the parameters as described above, is not economical at zero cost for wood fuel.

Large Industrial Load (Requiring a New Wood-Fired Boiler)

Consider the following as parameters for the typical installation.

- the wood-fired boiler capacity is 50 000 pph and will operate at 80 percent load factor.

  It will consume:
  51 713 tonnes (57 039 tons) of wood @ 80% MC (dry basis)
  40 220 tonnes (44 363 tons) of wood @ 40% MC
  35 930 tonnes (39 631 tons) of wood @ 25% MC.

  It will displace 11 034 000 litres (2 430 000 Imp. Gallons per year) of Bunker C oil.

- the increase in operating costs are:

  - allowance for additional operating staff = $180 000
  - allowance for additional insurance = 60 000
  - allowance for maintenance and servicing = 140 000

- the capital cost after allowing for a 15 percent grant is $3 608 000.

- the simple payback period is assumed to be 3 years.

Allowance for wood cost developed as follows:

Ratio of $\frac{\text{Net Savings}}{\text{Investment}}$ = 0.33

Net savings = oil fuel savings - wood fuel cost - extra expenses
= 0.33 x 3 608 000
= $1 190 640
= $2 427 480 - wood fuel cost - $380 000.

Wood fuel cost allowance = $856 840 (delivered to the plant).

This equates with: $16.57/tonne ($15.03/ton) @ 80 percent MC
$21.30/tonne ($19.33/ton) @ 40 percent MC
$23.85/tonne ($21.64/ton) @ 25 percent MC.

Large Industrial Load (With Wood-Fired Boiler in Place)

Consider the following as parameters for the typical installation.

- the wood-fired boiler (existing) has need for an additional 30 000 tonnes (33,068 tons) per year of 80 MC wood fuel. It is to operate at a conversion efficiency of 65 percent. This equates with an input of 0.329×10^{12} kJ - ($.311 \times 10^{12}$ Btu's) per year and an output of 0.213×10^{12} kJ - ($.202 \times 10^{12}$ Btu's).

- it will consume:

  29 831 tonnes (32 904 tons) of 80% MC (dry basis) wood fuel/year
  23 201 tonnes (25 590 tons) of 40% MC wood fuel/year
  20 726 tonnes (22 861 tons) of 25% MC wood fuel/year.

- the wood fuel will displace an estimated 6 365 049 litres (1,400,000 Imp gallons) of #6 oil/year.

- the increase in operating costs are:

  - allowance for additional operating staff = $120 000
  - allowance for additional maintenance and servicing = $ 40 000
  - allowance for incentive @ 25 percent of gross oil savings (Profit) = $350 077

Allowance for wood cost developed as follows:

- wood fuel allowance = oil savings - extra expenses - Profit
  = $1 400 310 - $160 000 - $350 077
  = $ 890 233

  = $29.84/tonne ($27.07/ton) of 80 percent MC wood
  = $38.37/tonne ($34.81/ton) of 40 percent MC wood
  = $42.95/tonne ($38.97/ton) of 25 percent MC wood.

The net savings are $350 077.